US009282656B2

(12) United States Patent
Degner et al.

(10) **Patent No.: US 9,282,656 B2**

(45) **Date of Patent: Mar. 8, 2016**

(54) **GASKETS FOR THERMAL DUCTING AROUND HEAT PIPES**

(71) Applicant: **Apple Inc.**, Cupertino, CA (US)

(72) Inventors: **Brett W. Degner**, Menlo Park, CA (US); **William F. Leggett**, Cupertino, CA (US); **Jay S. Nigen**, Mountain View, CA (US); **Frank F. Liang**, San Jose, CA (US); **Richard H. Tan**, Fremont, CA (US)

(73) Assignee: **Apple Inc.**, Cupertino, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 351 days.

(21) Appl. No.: **13/719,022**

(22) Filed: **Dec. 18, 2012**

(65) **Prior Publication Data**

US 2013/0329357 A1 Dec. 12, 2013

Related U.S. Application Data

(60) Provisional application No. 61/657,532, filed on Jun. 8, 2012, provisional application No. 61/657,454, filed on Jun. 8, 2012.

(51) **Int. Cl.**

G06F 1/16	(2006.01)
H05K 5/00	(2006.01)
H05K 7/00	(2006.01)
H05K 5/02	(2006.01)
F28D 15/02	(2006.01)
B23P 15/26	(2006.01)
H05K 7/20	(2006.01)
G06F 1/20	(2006.01)
F28D 1/02	(2006.01)

(52) **U.S. Cl.**

CPC . ***H05K 5/02*** (2013.01); ***B23P 15/26*** (2013.01); ***F28D 15/02*** (2013.01); ***F28D 15/0275*** (2013.01); ***G06F 1/203*** (2013.01); ***H05K 7/20336*** (2013.01); *F28D 1/024* (2013.01); *Y10T 29/49826* (2015.01)

(58) **Field of Classification Search**

CPC G06F 1/20; G06F 1/203; G06F 1/206

USPC 361/679.46, 679.47, 679.52, 679.55, 361/679.56, 679.3, 679.26, 679.21

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,405,930	B2 *	7/2008	Hongo et al.	361/679.48
2005/0276018	A1 *	12/2005	Moore et al.	361/695

* cited by examiner

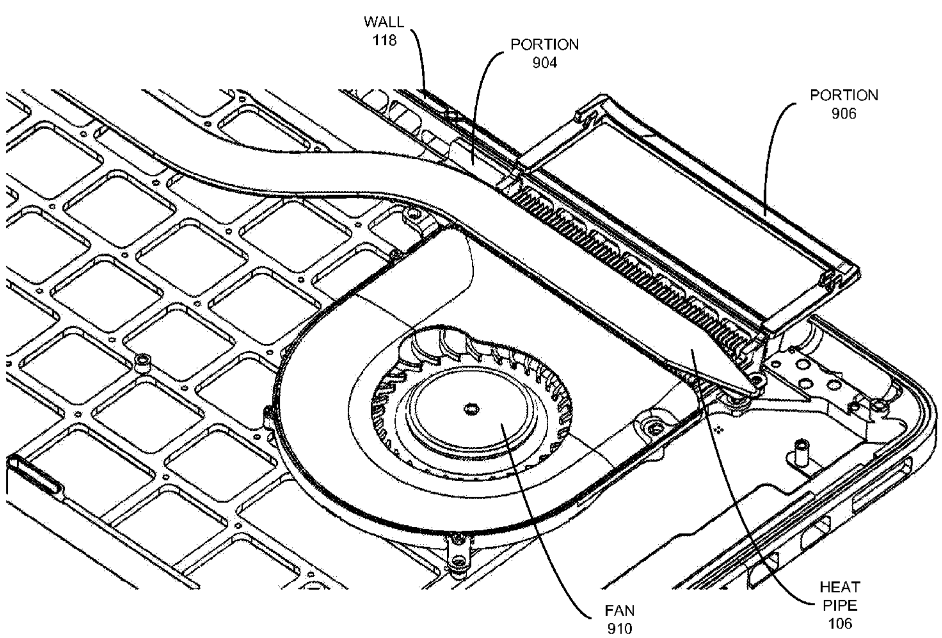
Primary Examiner — Anthony Haughton

(74) *Attorney, Agent, or Firm* — Downey Brand LLP

(57) **ABSTRACT**

The disclosed embodiments provide a component for a portable electronic device. The component includes a gasket containing a rigid portion disposed around a bottom of a heat pipe, wherein the rigid portion forms a duct between a fan and an exhaust vent of the electronic device. The gasket also includes a first flexible portion bonded to the rigid portion, wherein the first flexible portion comprises a flap that is open during assembly of the heat pipe in the electronic device and closed over the heat pipe and the rigid portion to seal the duct around the heat pipe after the assembly.

29 Claims, 19 Drawing Sheets



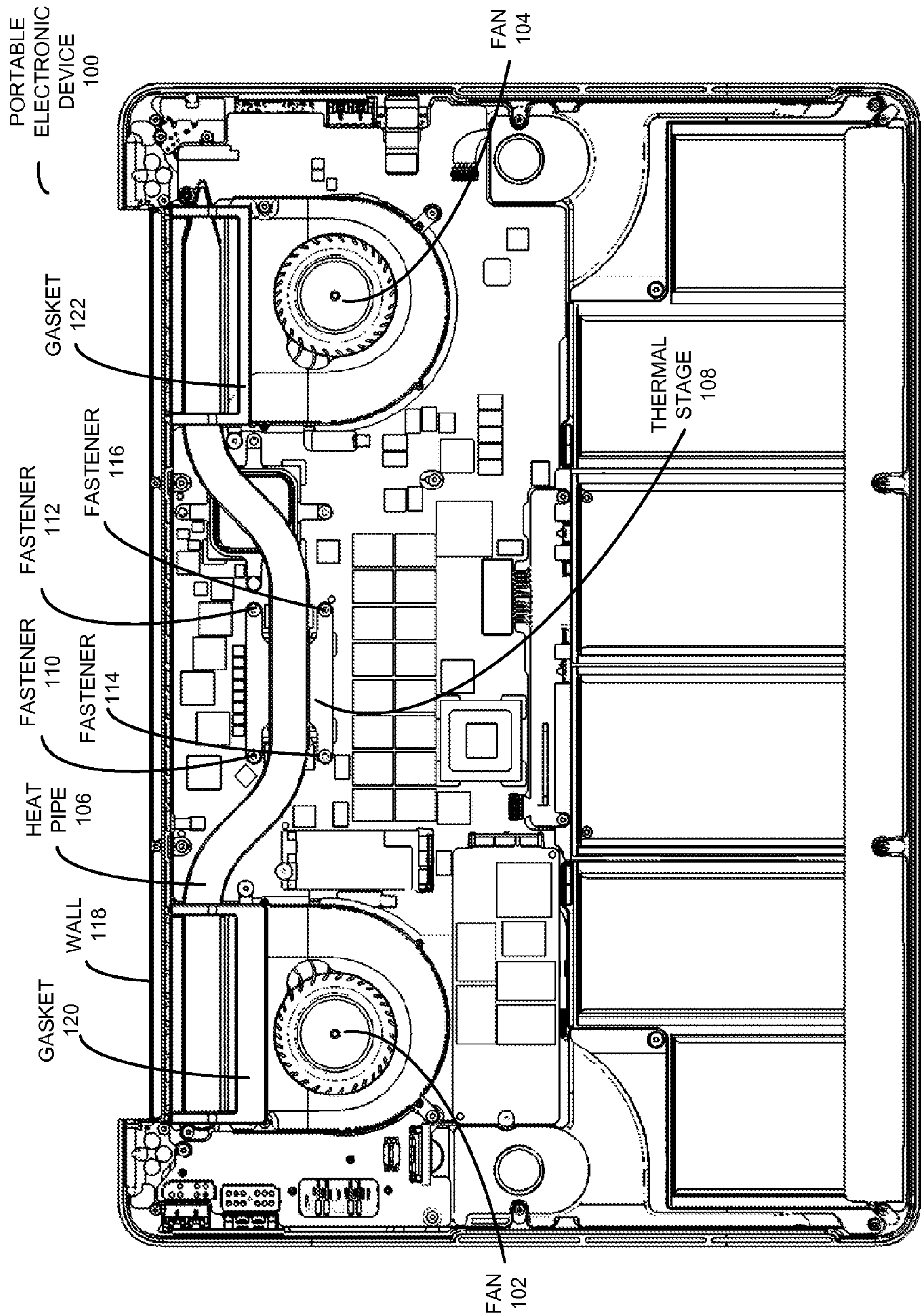

PORTABLE ELECTRONIC DEVICE 100
FAN 104
GASKET 122
THERMAL STAGE 108
FASTENER 116
FASTENER 112
FASTENER 110
FASTENER 114
HEAT PIPE 106
WALL 118
GASKET 120
FAN 102

FIG. 1

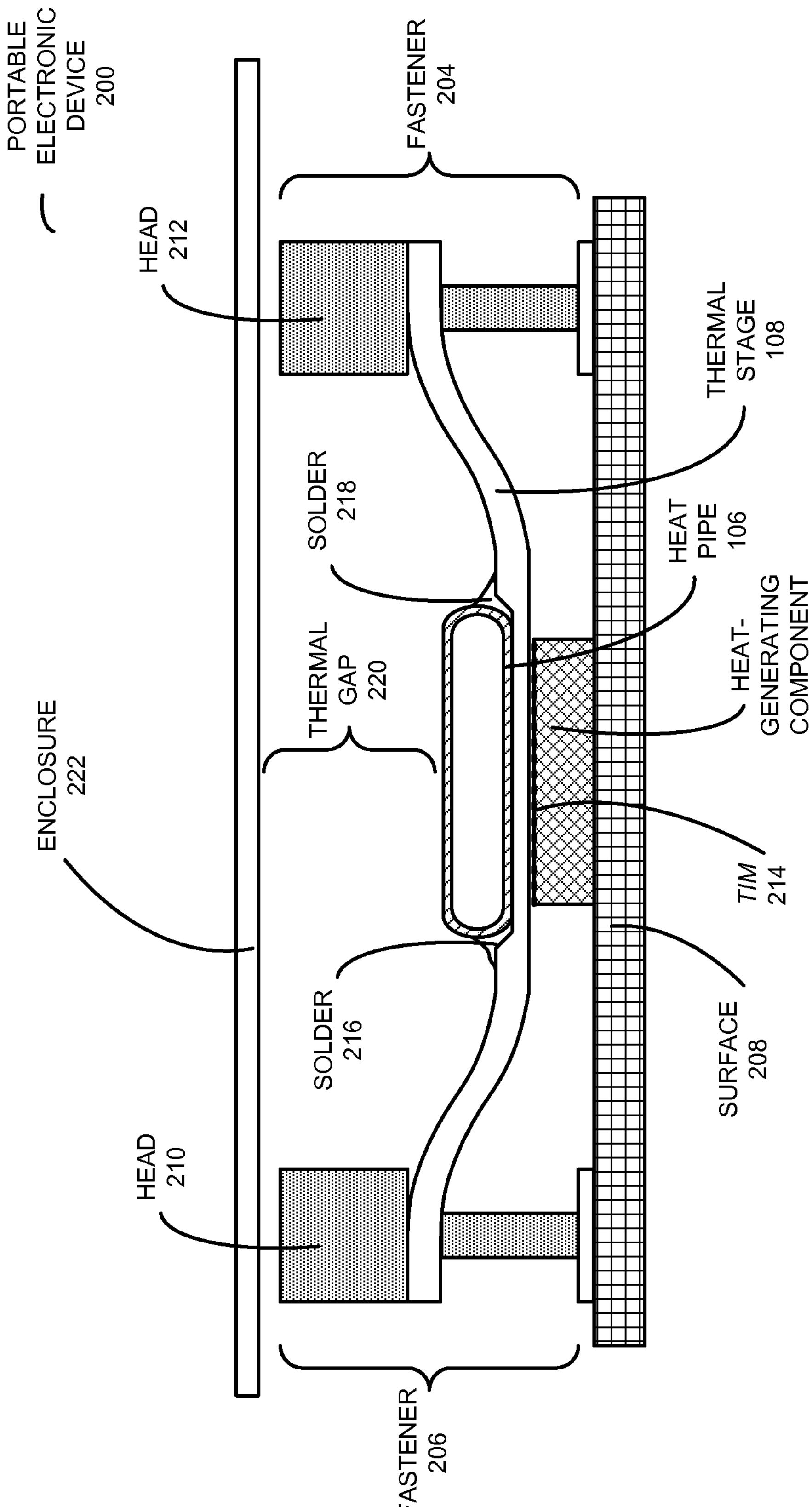

PORTABLE ELECTRONIC DEVICE 200
FASTENER 204
HEAD 212
THERMAL STAGE 108
SOLDER 218
HEAT PIPE 106
THERMAL GAP 220
HEAT-GENERATING COMPONENT 202
ENCLOSURE 222
TIM 214
SOLDER 216
SURFACE 208
HEAD 210
FASTENER 206

FIG. 2

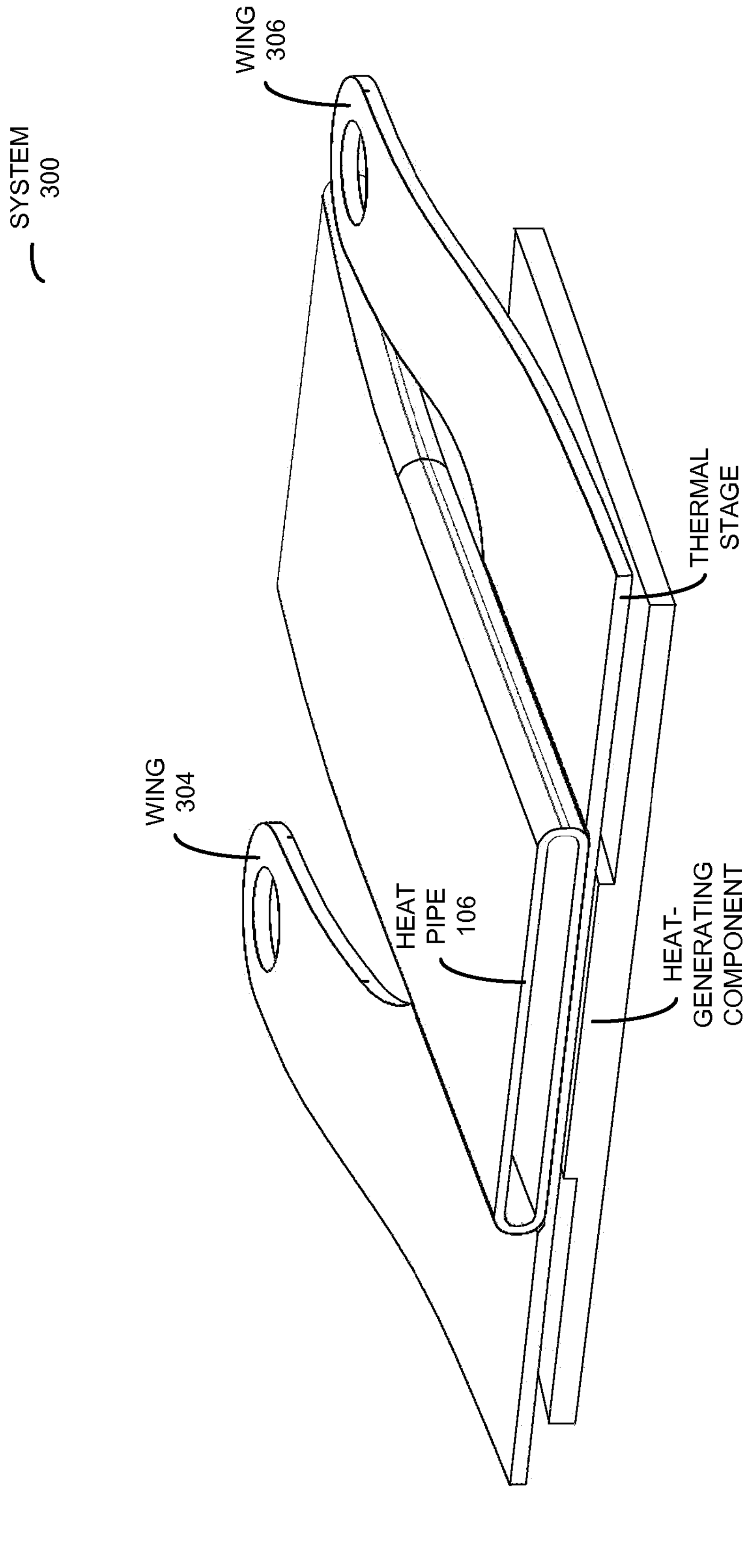

SYSTEM
300
WING
306
THERMAL
STAGE
108
WING
304
HEAT
PIPE
106
HEAT-
GENERATING
COMPONENT
302

FIG. 3

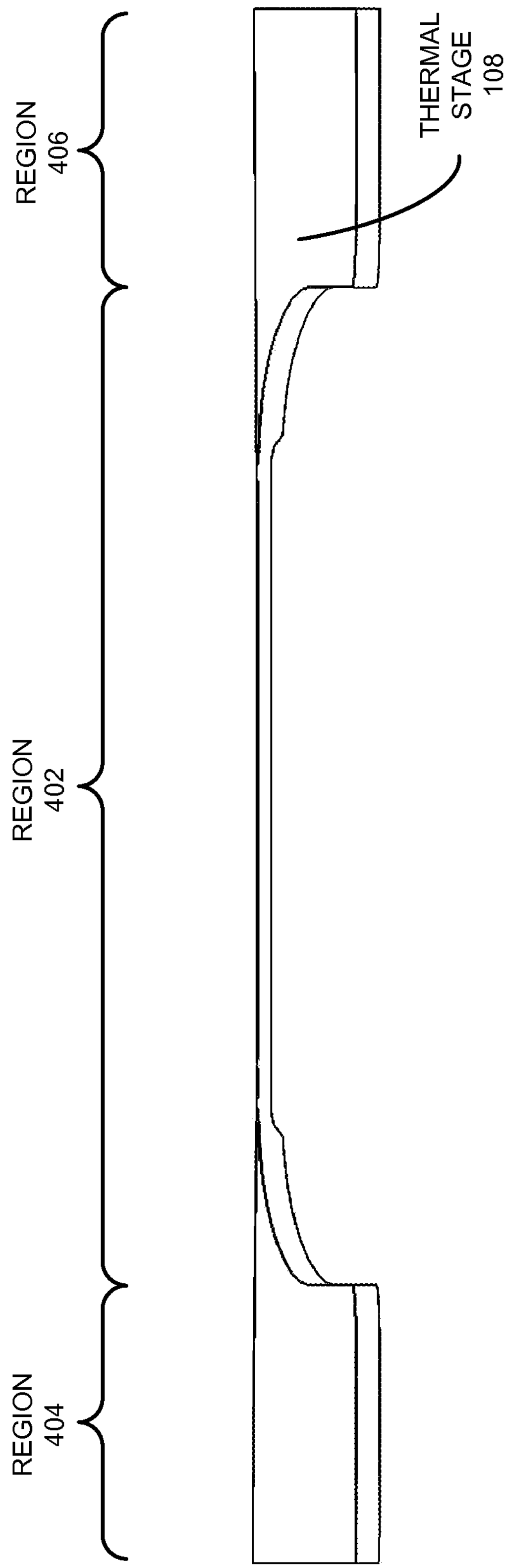


FIG. 4

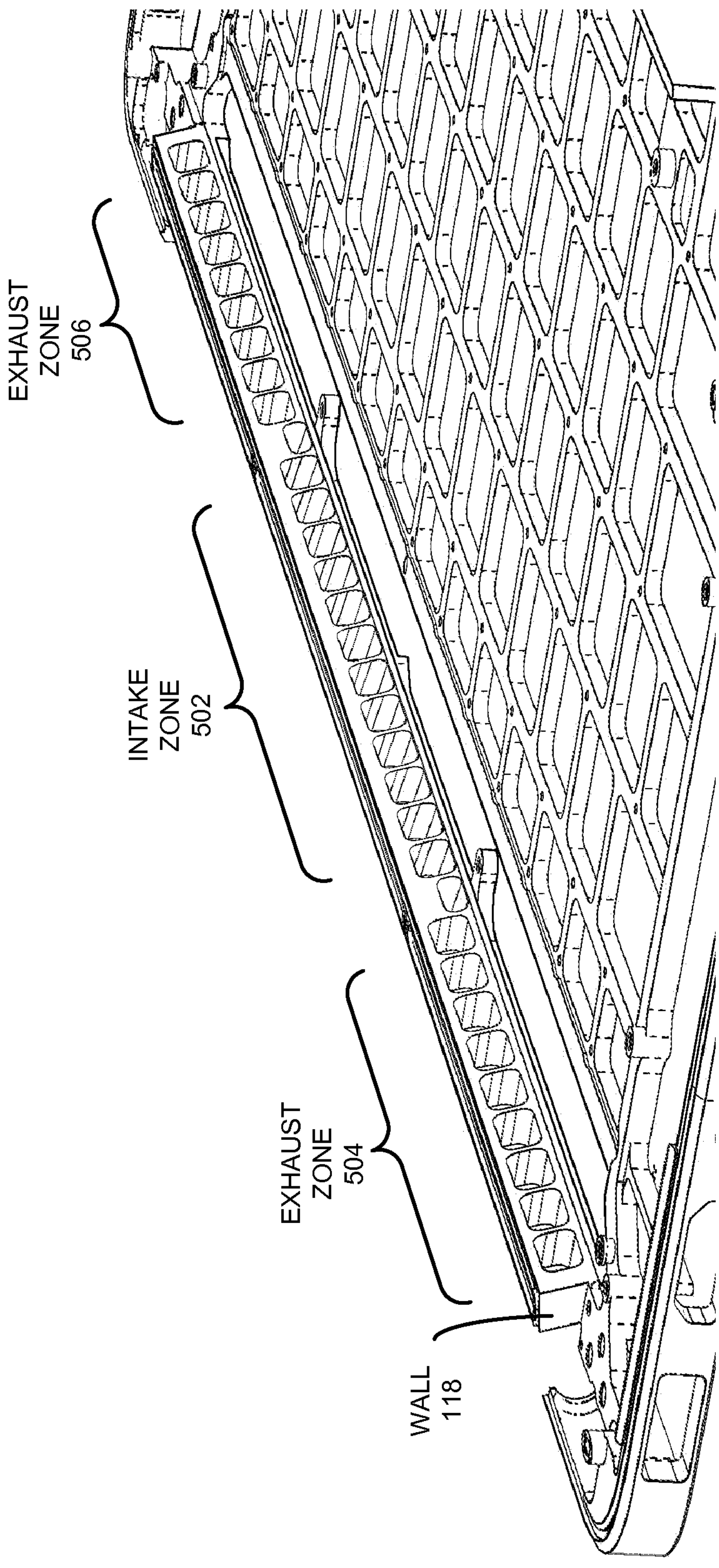


FIG. 5

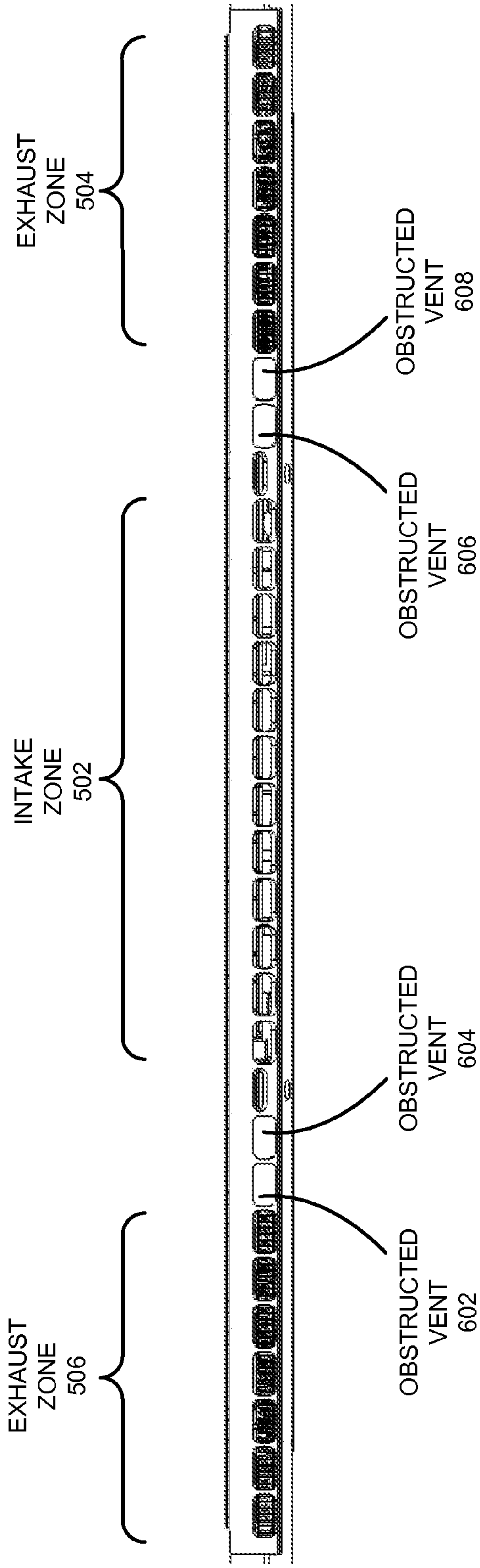

EXHAUST ZONE 504
OBSTRUCTED VENT 608
OBSTRUCTED VENT 606
INTAKE ZONE 502
OBSTRUCTED VENT 604
OBSTRUCTED VENT 602
EXHAUST ZONE 506

FIG. 6

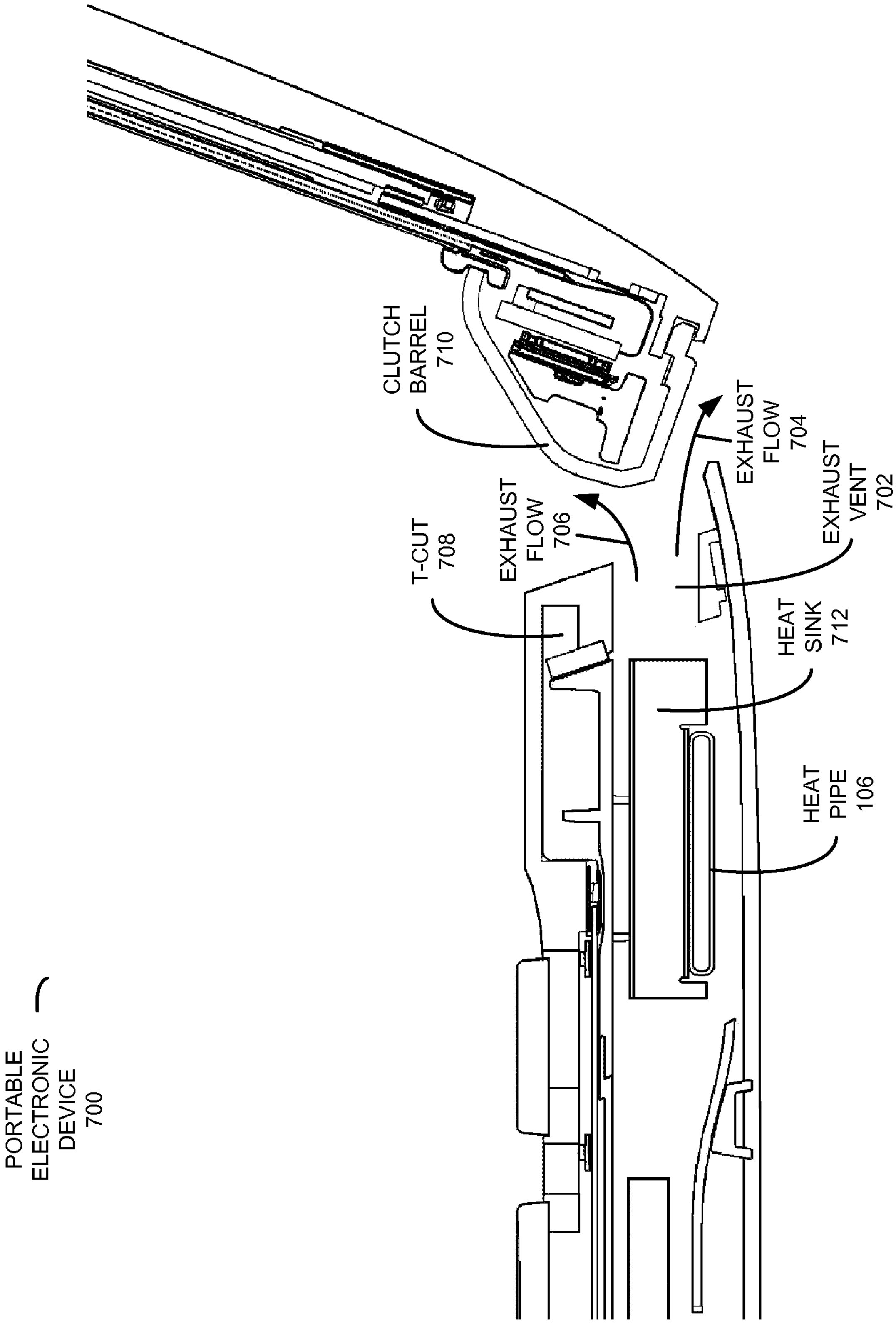

PORTABLE ELECTRONIC DEVICE 700
CLUTCH BARREL 710
T-CUT 708
EXHAUST FLOW 706
EXHAUST FLOW 704
EXHAUST VENT 702
HEAT SINK 712
HEAT PIPE 106

FIG. 7

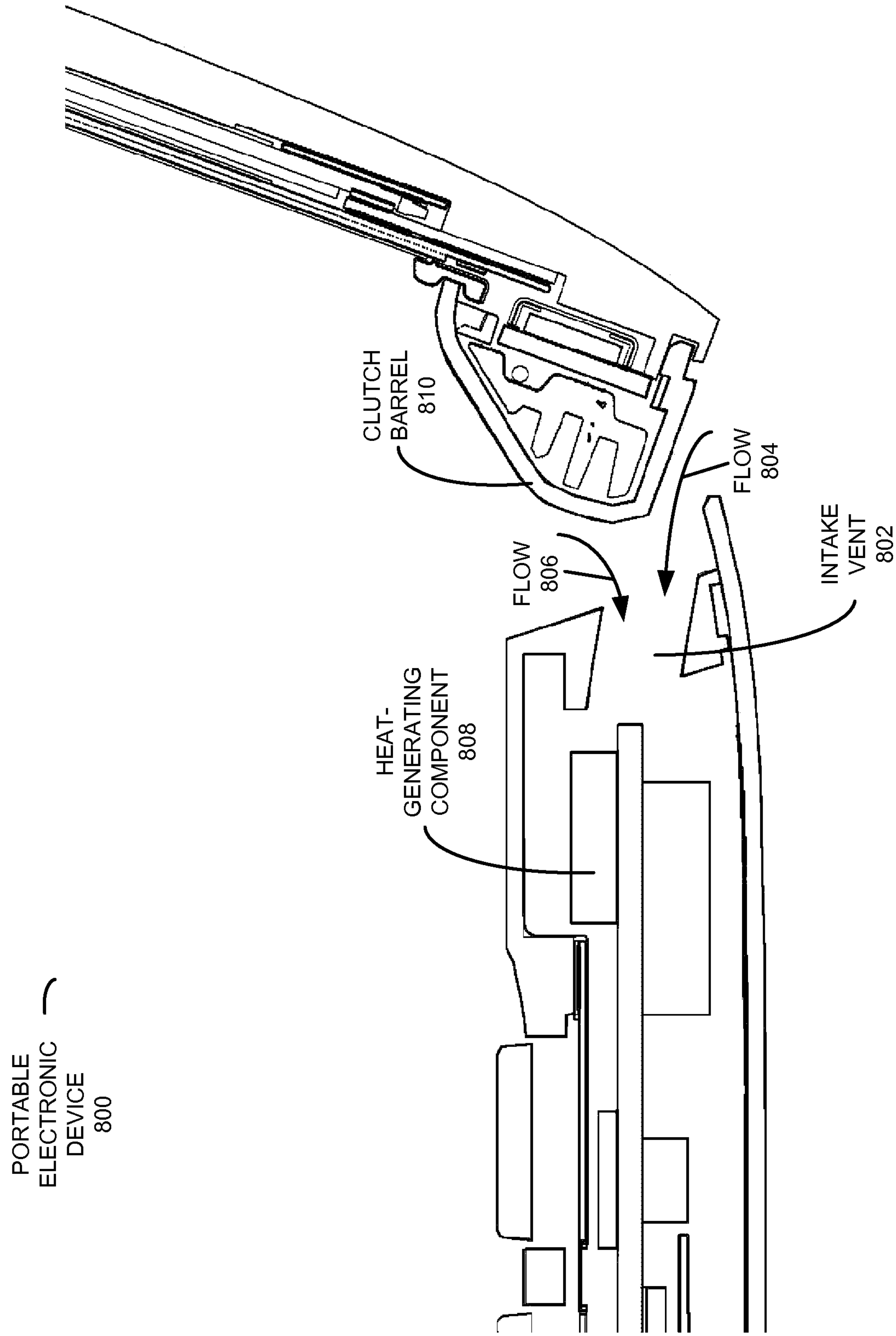

CLUTCH BARREL 810
FLOW 804
INTAKE VENT 802
FLOW 806
HEAT-GENERATING COMPONENT 808
PORTABLE ELECTRONIC DEVICE 800

FIG. 8

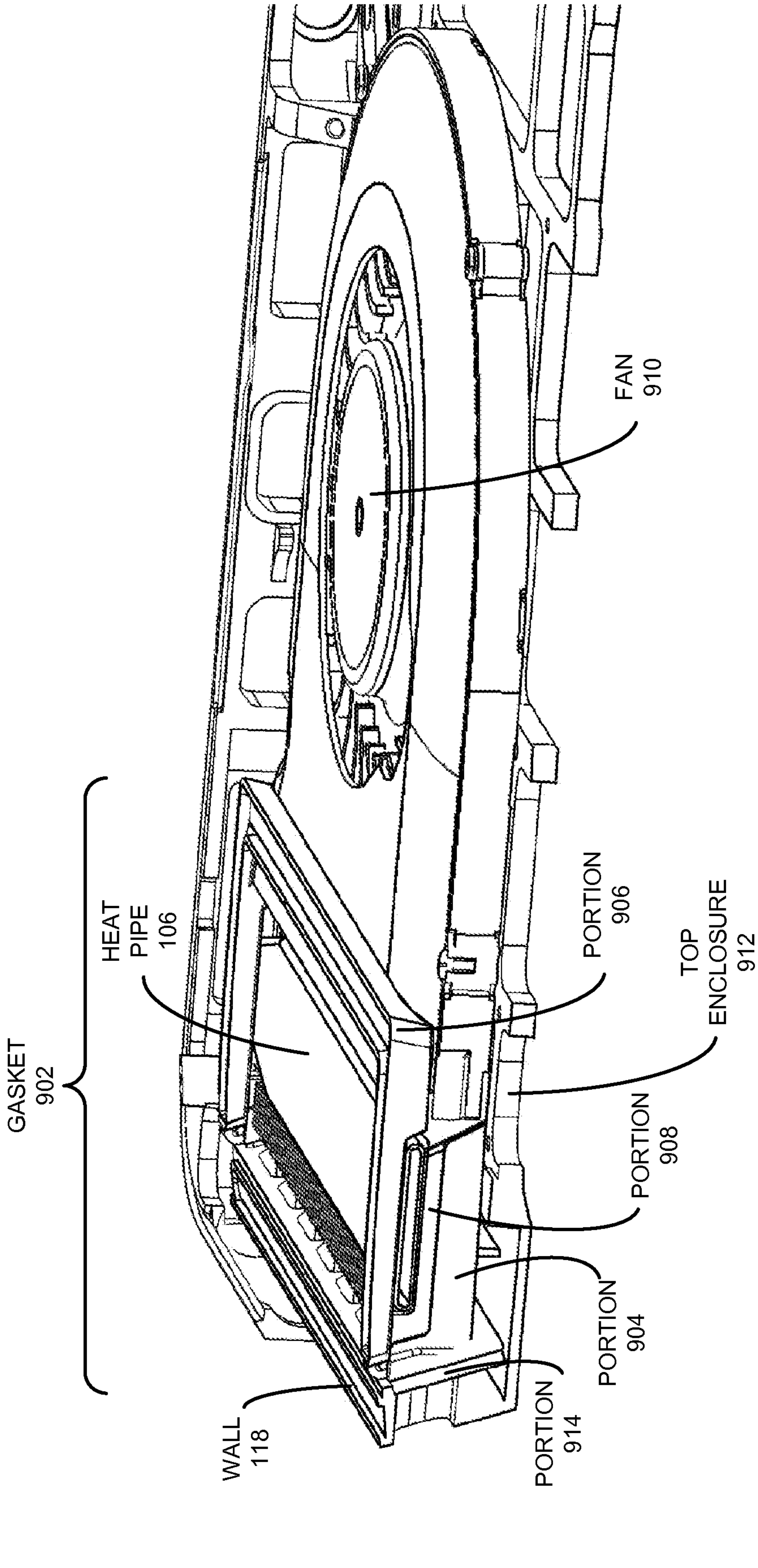

FAN
910
HEAT
PIPE
106
PORTION
906
TOP
ENCLOSURE
912
GASKET
902
PORTION
908
PORTION
904
WALL
118
PORTION
914

FIG. 9

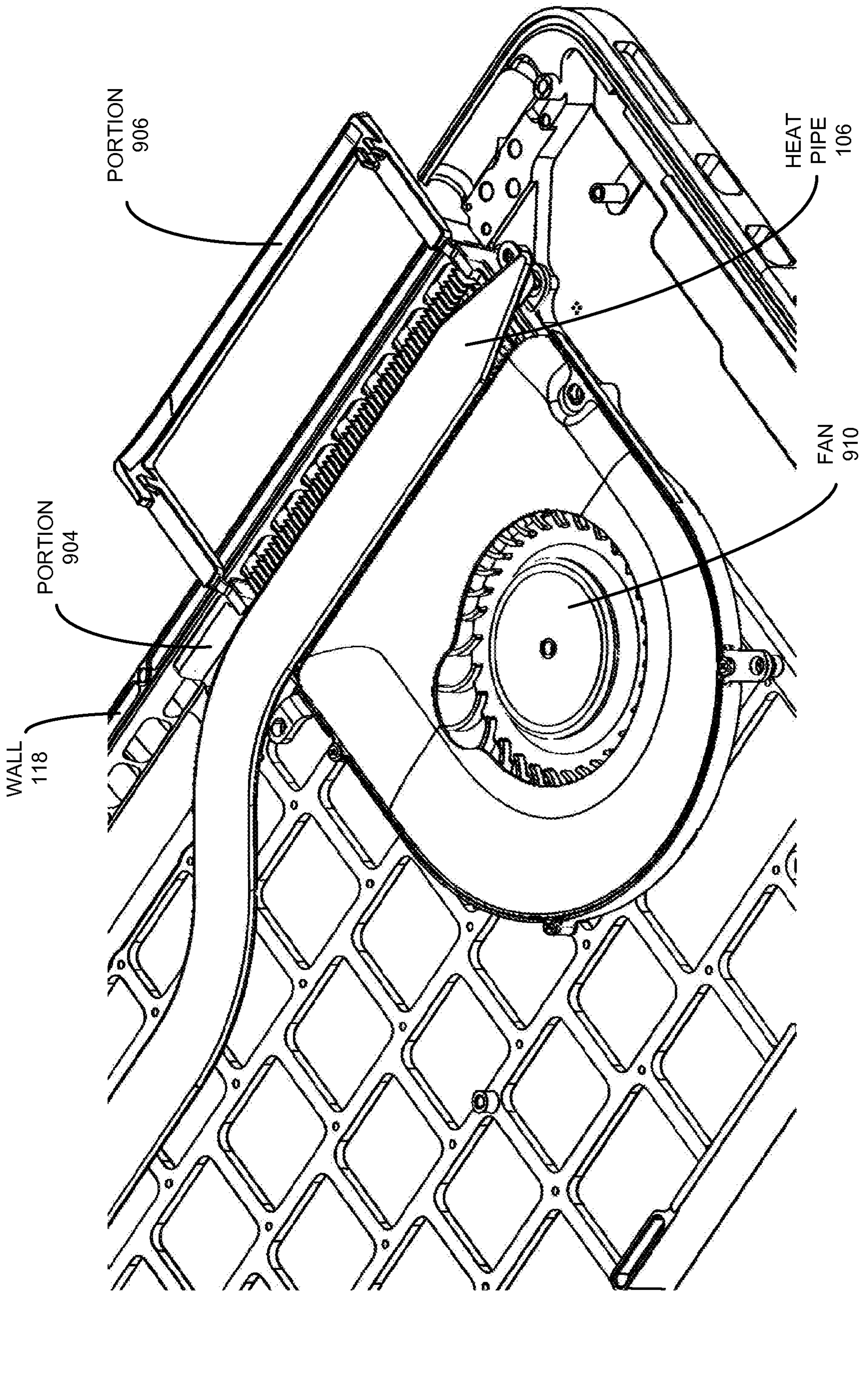


FIG. 10

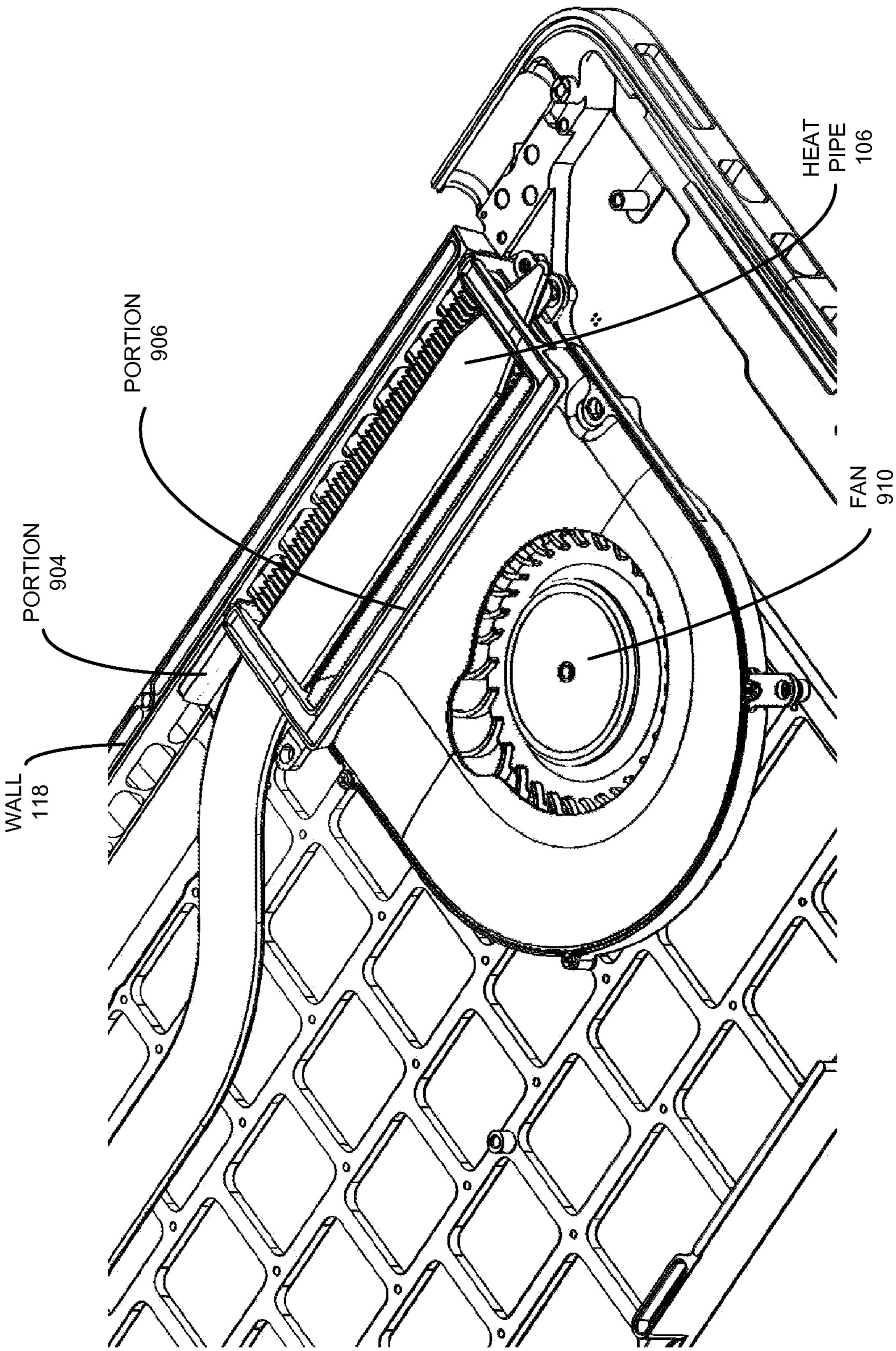


FIG. 11

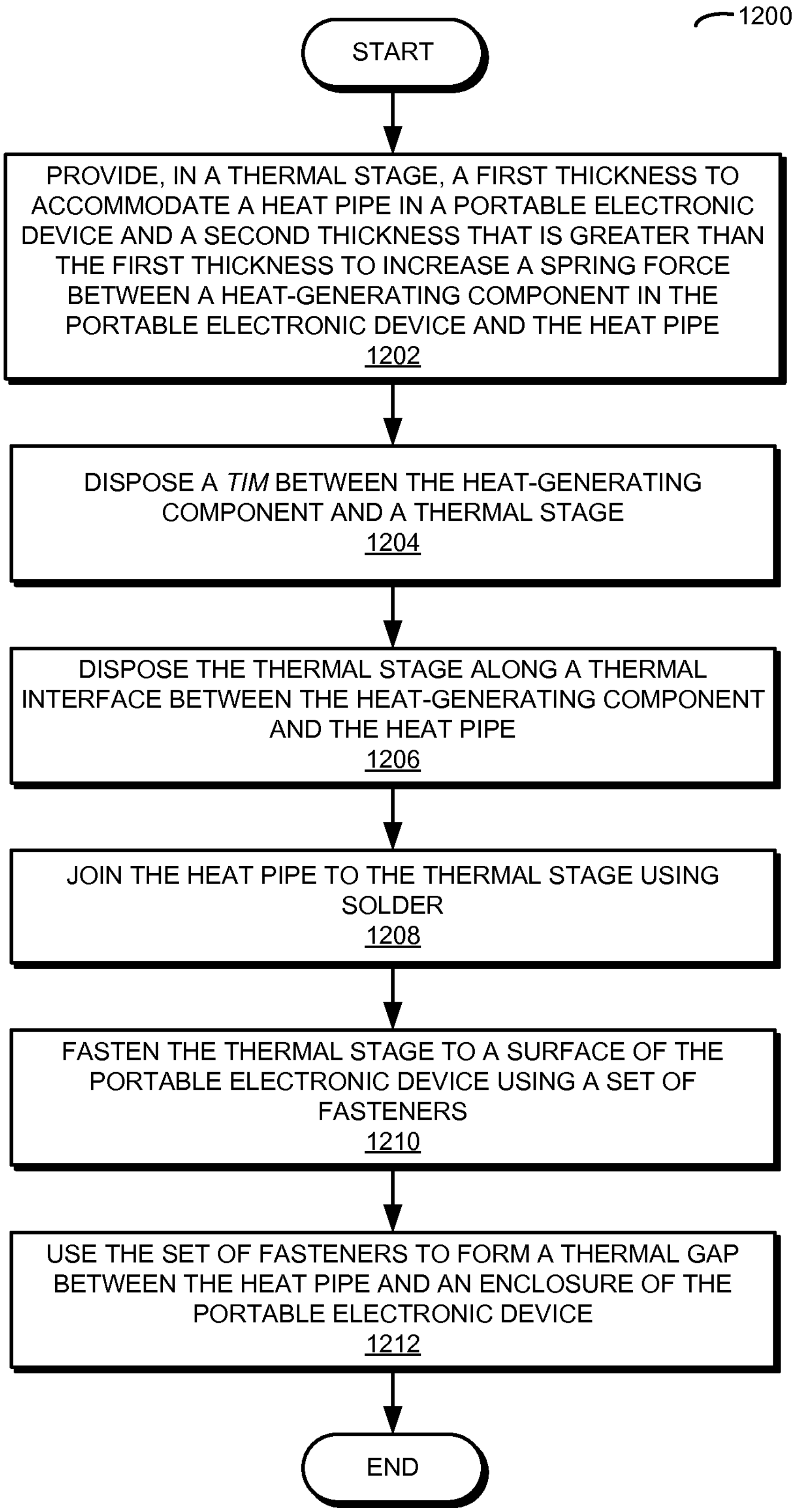

1200
START
PROVIDE, IN A THERMAL STAGE, A FIRST THICKNESS TO ACCOMMODATE A HEAT PIPE IN A PORTABLE ELECTRONIC DEVICE AND A SECOND THICKNESS THAT IS GREATER THAN THE FIRST THICKNESS TO INCREASE A SPRING FORCE BETWEEN A HEAT-GENERATING COMPONENT IN THE PORTABLE ELECTRONIC DEVICE AND THE HEAT PIPE 1202
DISPOSE A *TIM* BETWEEN THE HEAT-GENERATING COMPONENT AND A THERMAL STAGE 1204
DISPOSE THE THERMAL STAGE ALONG A THERMAL INTERFACE BETWEEN THE HEAT-GENERATING COMPONENT AND THE HEAT PIPE 1206
JOIN THE HEAT PIPE TO THE THERMAL STAGE USING SOLDER 1208
FASTEN THE THERMAL STAGE TO A SURFACE OF THE PORTABLE ELECTRONIC DEVICE USING A SET OF FASTENERS 1210
USE THE SET OF FASTENERS TO FORM A THERMAL GAP BETWEEN THE HEAT PIPE AND AN ENCLOSURE OF THE PORTABLE ELECTRONIC DEVICE 1212
END

FIG. 12

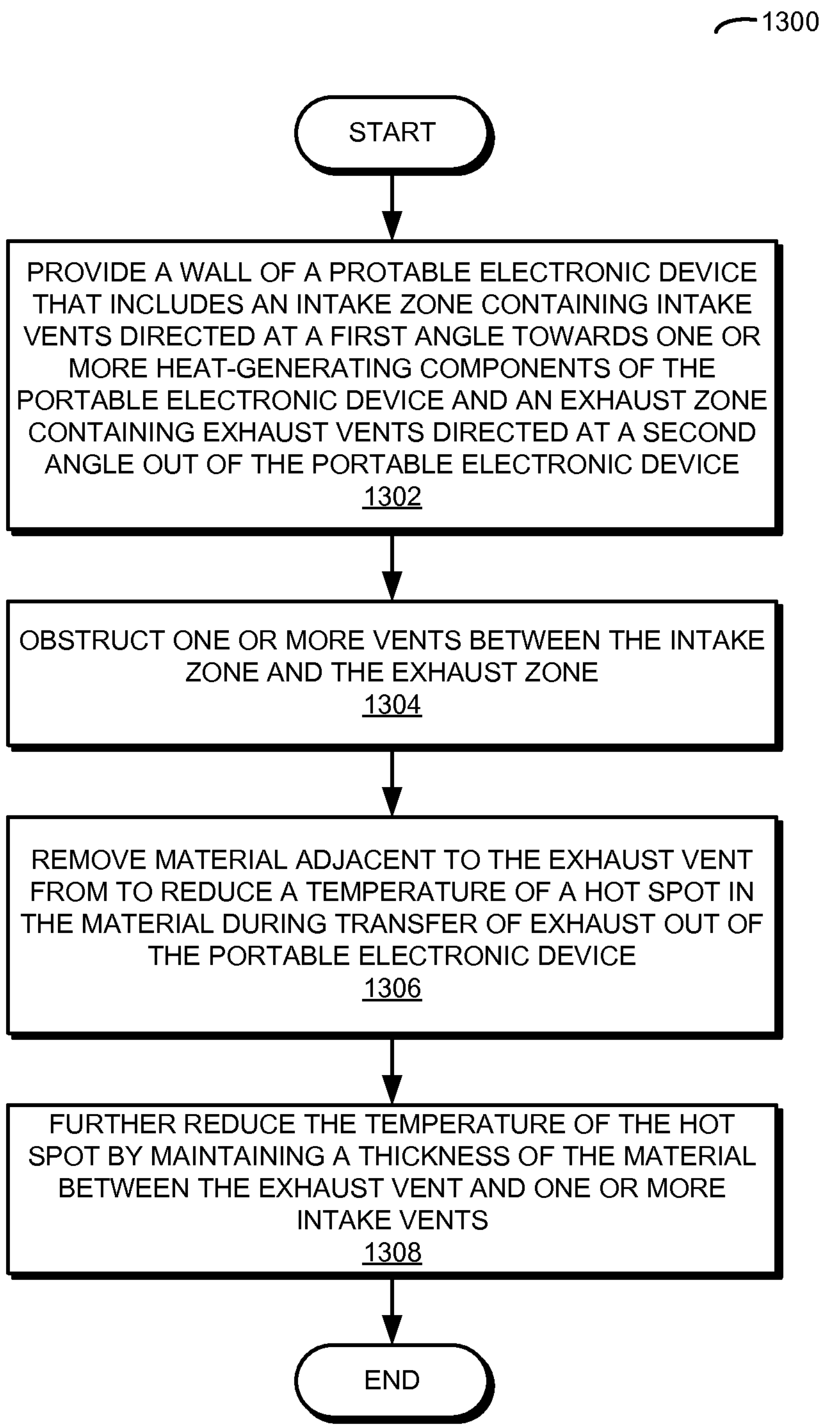

1300
START
PROVIDE A WALL OF A PROTABLE ELECTRONIC DEVICE THAT INCLUDES AN INTAKE ZONE CONTAINING INTAKE VENTS DIRECTED AT A FIRST ANGLE TOWARDS ONE OR MORE HEAT-GENERATING COMPONENTS OF THE PORTABLE ELECTRONIC DEVICE AND AN EXHAUST ZONE CONTAINING EXHAUST VENTS DIRECTED AT A SECOND ANGLE OUT OF THE PORTABLE ELECTRONIC DEVICE
1302
OBSTRUCT ONE OR MORE VENTS BETWEEN THE INTAKE ZONE AND THE EXHAUST ZONE
1304
REMOVE MATERIAL ADJACENT TO THE EXHAUST VENT FROM TO REDUCE A TEMPERATURE OF A HOT SPOT IN THE MATERIAL DURING TRANSFER OF EXHAUST OUT OF THE PORTABLE ELECTRONIC DEVICE
1306
FURTHER REDUCE THE TEMPERATURE OF THE HOT SPOT BY MAINTAINING A THICKNESS OF THE MATERIAL BETWEEN THE EXHAUST VENT AND ONE OR MORE INTAKE VENTS
1308
END

FIG. 13

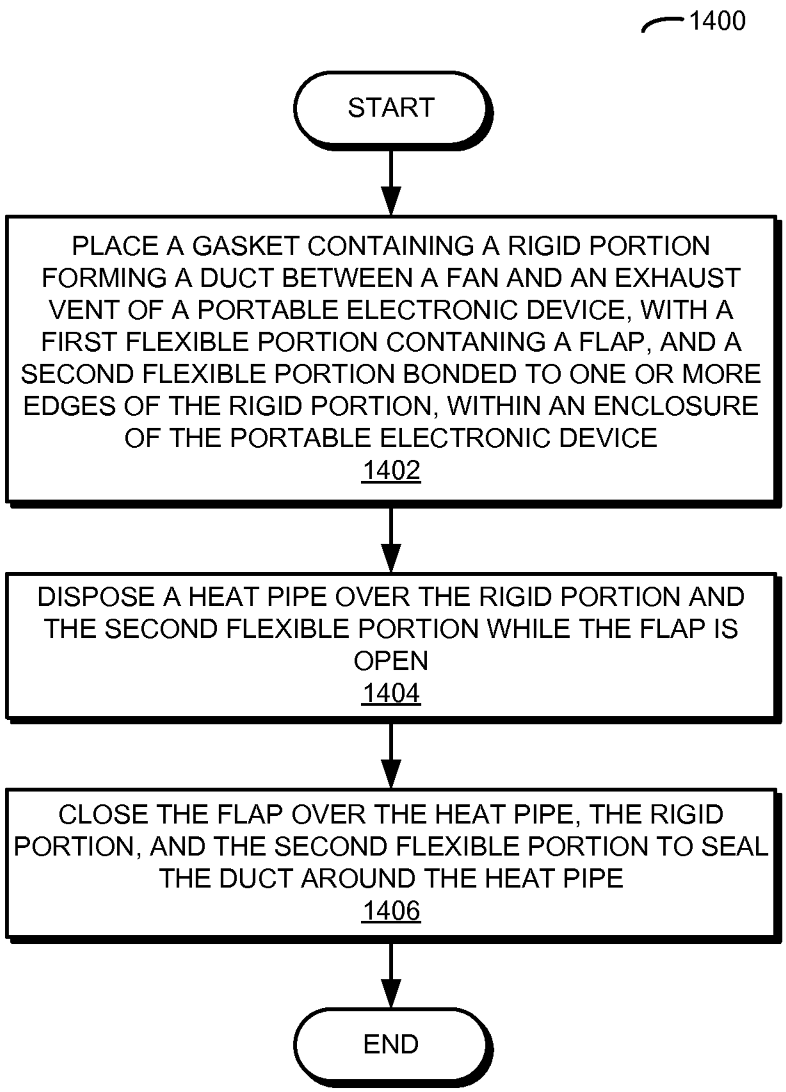

1400
START
PLACE A GASKET CONTAINING A RIGID PORTION FORMING A DUCT BETWEEN A FAN AND AN EXHAUST VENT OF A PORTABLE ELECTRONIC DEVICE, WITH A FIRST FLEXIBLE PORTION CONTANING A FLAP, AND A SECOND FLEXIBLE PORTION BONDED TO ONE OR MORE EDGES OF THE RIGID PORTION, WITHIN AN ENCLOSURE OF THE PORTABLE ELECTRONIC DEVICE
1402
DISPOSE A HEAT PIPE OVER THE RIGID PORTION AND THE SECOND FLEXIBLE PORTION WHILE THE FLAP IS OPEN
1404
CLOSE THE FLAP OVER THE HEAT PIPE, THE RIGID PORTION, AND THE SECOND FLEXIBLE PORTION TO SEAL THE DUCT AROUND THE HEAT PIPE
1406
END

FIG. 14

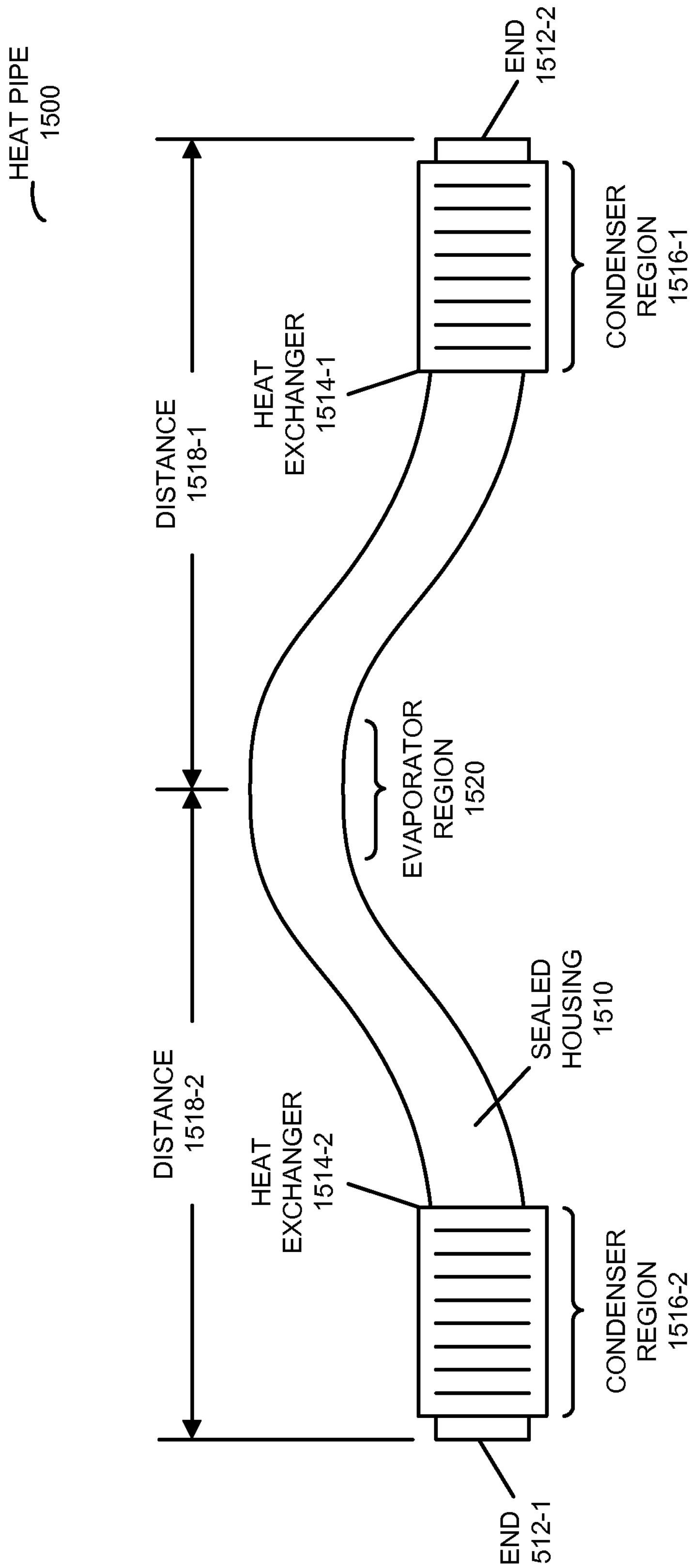

HEAT PIPE
1500
END
1512-2
HEAT
EXCHANGER
1514-1
CONDENSER
REGION
1516-1
DISTANCE
1518-1
EVAPORATOR
REGION
1520
SEALED
HOUSING
1510
DISTANCE
1518-2
HEAT
EXCHANGER
1514-2
CONDENSER
REGION
1516-2
END
1512-1

FIG. 15

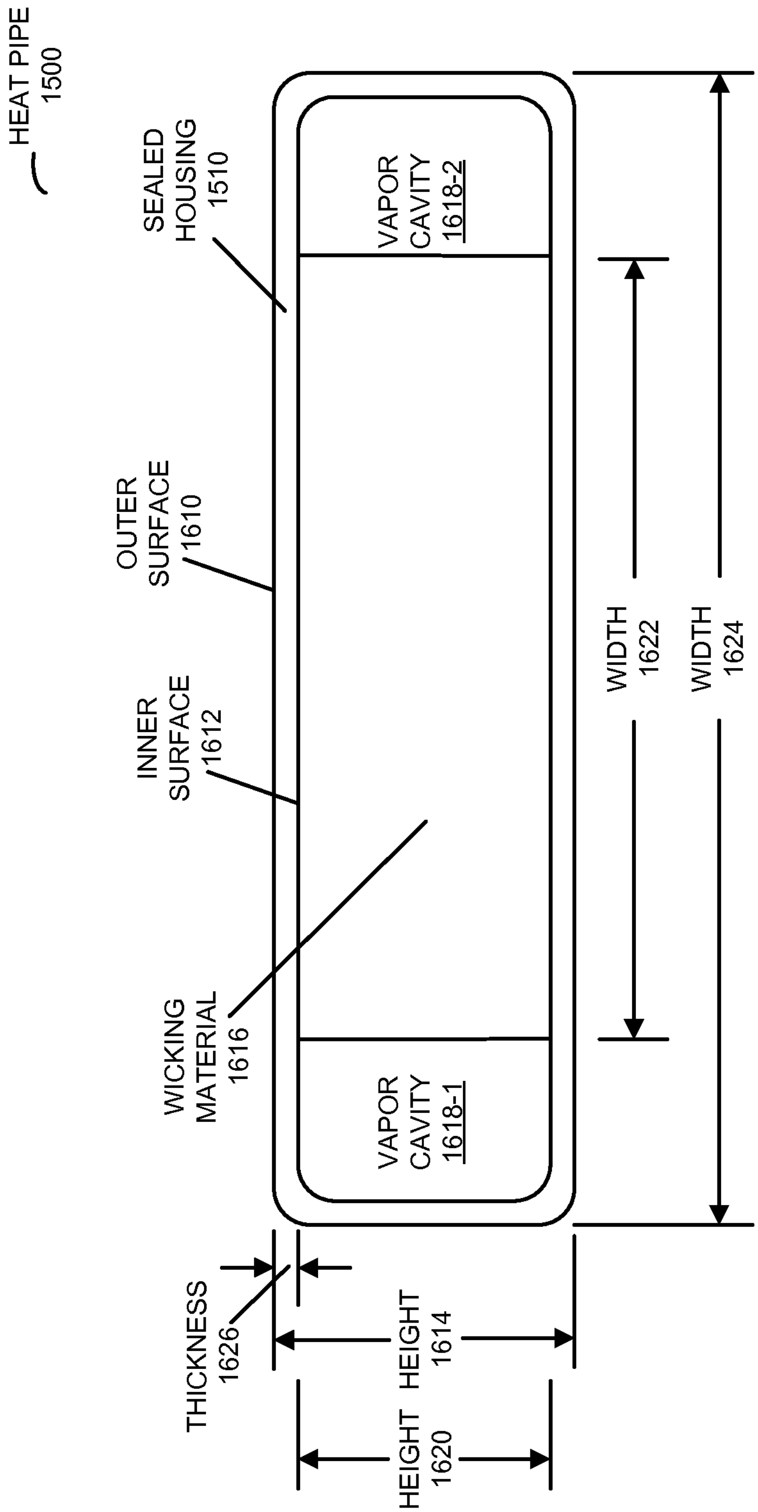

HEAT PIPE 1500
SEALED HOUSING 1510
OUTER SURFACE 1610
INNER SURFACE 1612
WICKING MATERIAL 1616
VAPOR CAVITY 1618-2
VAPOR CAVITY 1618-1
WIDTH 1622
WIDTH 1624
THICKNESS 1626
HEIGHT 1614
HEIGHT 1620

FIG. 16

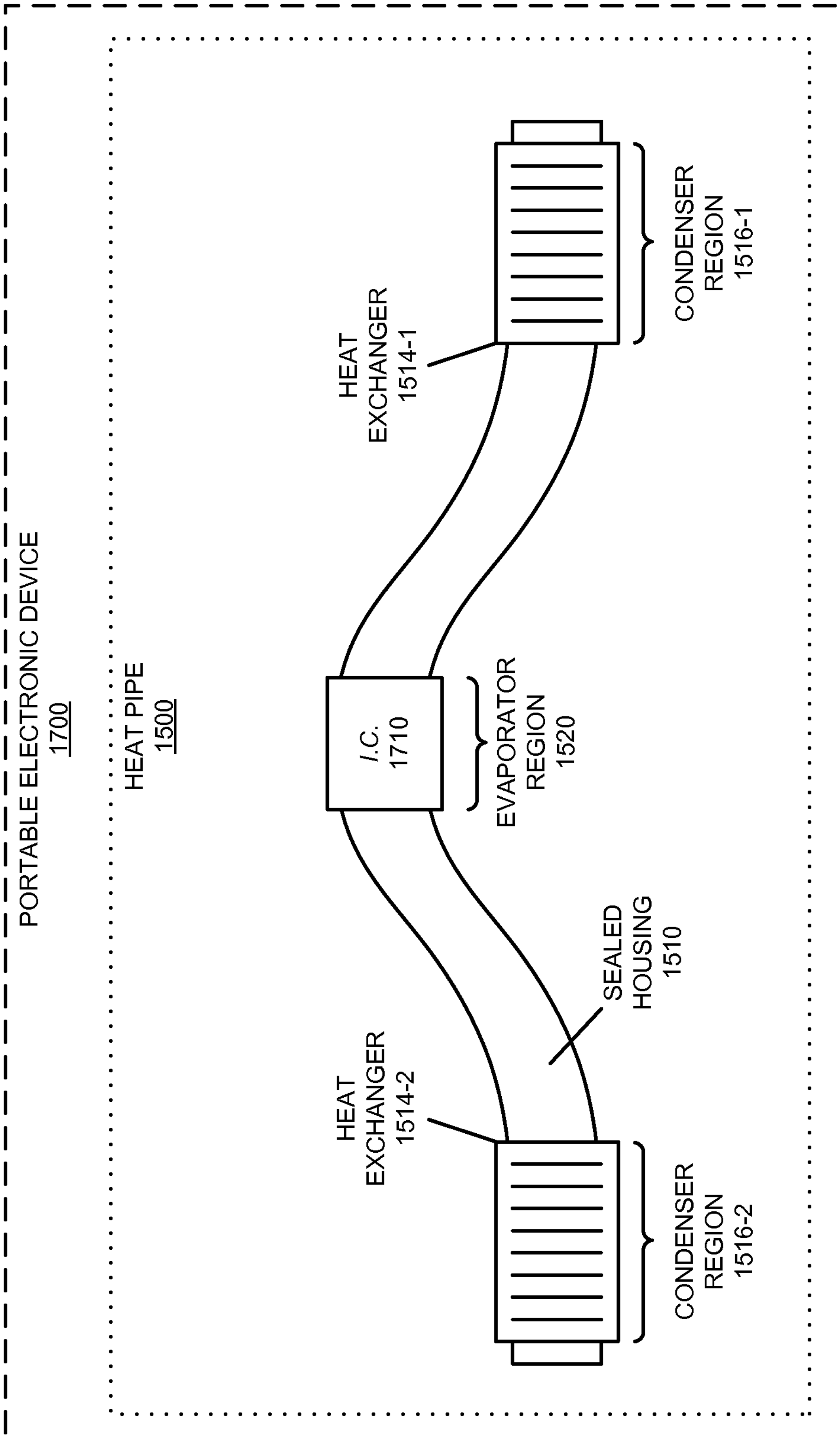

PORTABLE ELECTRONIC DEVICE
1700
HEAT PIPE
1500
HEAT EXCHANGER
1514-1
CONDENSER REGION
1516-1
I.C.
1710
EVAPORATOR REGION
1520
SEALED HOUSING
1510
HEAT EXCHANGER
1514-2
CONDENSER REGION
1516-2

FIG. 17

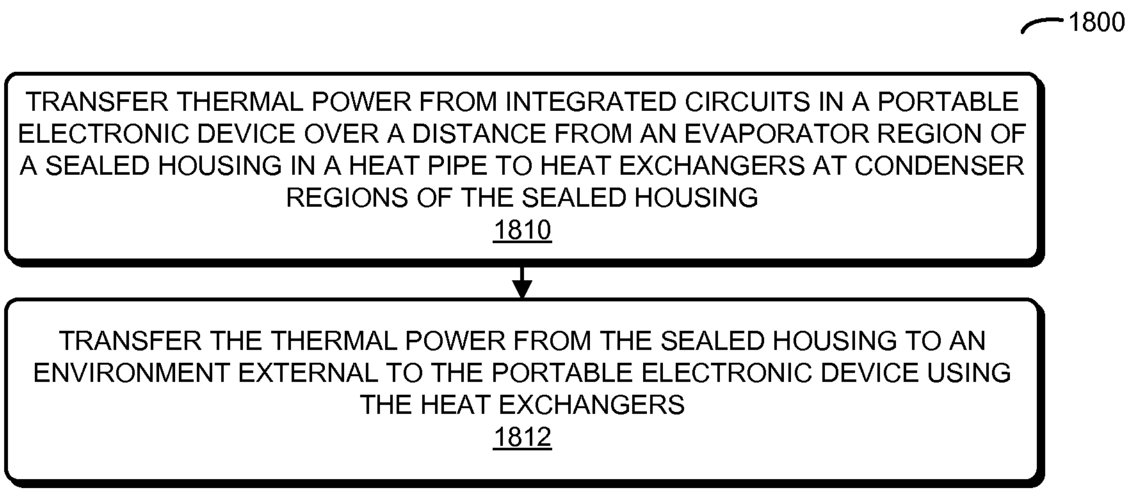

1800
TRANSFER THERMAL POWER FROM INTEGRATED CIRCUITS IN A PORTABLE ELECTRONIC DEVICE OVER A DISTANCE FROM AN EVAPORATOR REGION OF A SEALED HOUSING IN A HEAT PIPE TO HEAT EXCHANGERS AT CONDENSER REGIONS OF THE SEALED HOUSING
1810
TRANSFER THE THERMAL POWER FROM THE SEALED HOUSING TO AN ENVIRONMENT EXTERNAL TO THE PORTABLE ELECTRONIC DEVICE USING THE HEAT EXCHANGERS
1812

FIG. 18

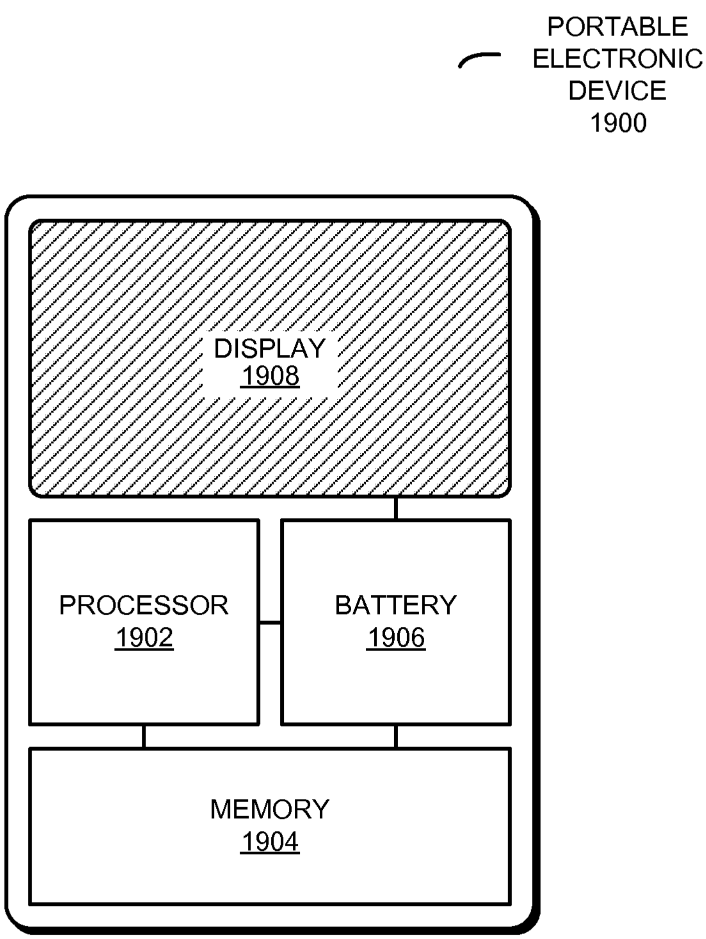

PORTABLE
ELECTRONIC
DEVICE
1900
DISPLAY
1908
PROCESSOR
1902
BATTERY
1906
MEMORY
1904

FIG. 19

GASKETS FOR THERMAL DUCTING AROUND HEAT PIPES

CROSS REFERENCE TO RELATED APPLICATION

This application claims priority under 35 U.S.C. §119(e) to: U.S. Provisional Application Ser. No. 61/657,532, entitled "Gaskets for Thermal Ducting Around Heat Pipes in Electronic Devices," by Brett W. Degner, William F. Leggett and Jay S. Nigen, filed on Jun. 8, 2012; and U.S. Provisional Application Ser. No. 61/657,454, entitled "Heat Pipe with Reduced Height," by Frank F. Liang, and Richard H. Tan, filed on Jun. 8, 2012, the contents of each of which are herein incorporated by reference.

This application is also related to: U.S. Provisional Application Ser. No. 61/657,534, entitled "Fasteners for Creating Thermal Gaps in Electronic Devices," by Brett W. Degner, Charles A. Schwalbach and William F. Leggett, filed on Jun. 8, 2012; U.S. Provisional Application Ser. No. 61/657,505, entitled "Optimized Vent Walls in Electronic Devices," by Brett W. Degner, Bart Andre, Jeremy D. Bataillou, Jay S. Nigen, Christian A. Ligtenberg, Ron A. Hopkinson, Charles A. Schwalbach, Matthew P. Casebolt, Nicholas A. Rundle and Frank F. Liang, filed on Jun. 8, 2012; and U.S. Provisional Application Ser. No. 61/657,538, entitled "Dual-Thickness Thermal Stages in Electronic Devices," by Brett W. Degner, Patrick Kessler, Charles A. Schwalbach and Richard H. Tan, filed on Jun. 8, 2012, the contents of all of which are herein incorporated by reference.

BACKGROUND

1. Field

The disclosed embodiments relate to techniques for facilitating heat transfer in portable electronic devices.

2. Related Art

A modern portable electronic device typically contains a set of tightly packed components. For example, a laptop computer may include a keyboard, display, speakers, touchpad, battery, buttons, processor, memory, internal storage, and/or ports in an enclosure that is less than one inch thick, 8-11 inches long, and 12-16 inches wide. Moreover, most components in the portable electronic device generate heat, which must be dissipated to enable safe use of the portable electronic device and improve long-term reliability. For example, heat generated by components in a laptop computer may be transferred away from the components and out of the laptop computer to prevent damage to the components and increase user comfort and safety while operating the laptop computer.

However, heat-dissipation mechanisms for portable electronic devices generally involve the use of additional parts and/or materials. For example, heat sinks, cooling fans, heat pipes, thermal spreaders, and/or vents may be used to dissipate heat from components in a laptop computer. Such heat-dissipating parts and/or materials may take up space within the portable electronic devices and may add to the cost of the portable electronic devices.

Hence, space-efficient designs for portable electronic devices may be facilitated by more efficient and/or smaller heat-dissipation mechanisms in the portable electronic devices.

SUMMARY

The described embodiments include a component for use in a portable electronic device. The component includes a gasket containing a rigid portion disposed around a bottom of a heat pipe, wherein the rigid portion forms a duct between a fan and an exhaust vent of the electronic device. The gasket also includes a first flexible portion bonded to the rigid portion, wherein the first flexible portion comprises a flap that is open during assembly of the heat pipe in the electronic device and closed over the heat pipe and the rigid portion to seal the duct around the heat pipe after the assembly.

In some embodiments, the gasket also includes a second flexible portion bonded to one or more edges of the rigid portion, wherein the second flexible portion contacts the first flexible portion and the heat pipe to further seal the duct around the heat pipe.

In some embodiments, the first and second flexible portions further seal the duct around at least one of the fan, a bottom enclosure of the electronic device, a top enclosure of the electronic device, and the exhaust vent.

In some embodiments, the first and second flexible portions are bonded to the rigid portion using an overmolding technique.

In some embodiments, the first and second flexible portions form a compression seal around the heat pipe.

In some embodiments, the rigid portion includes plastic.

In some embodiments, the first flexible portion includes a rubber.

Another embodiment provides a heat pipe that facilitates heat transfer. The heat pipe includes a sealed housing having an outer surface, an inner surface, two ends and a height less than a predetermined value, where the sealed housing includes a wicking material along at least at least a portion of the inner surface and vapor cavities, and the sealed cavity includes a thermal transport material in a liquid state. Moreover, the heat pipe includes heat exchangers (such as convective-cooling fins), thermally coupled to the sealed housing, at condenser regions of the sealed housing proximate to the ends of the sealed housing. During operation of the heat pipe, the sealed housing supports a two-phase bidirectional flow of the thermal transport material in the liquid state in the wicking material and in a gas state in the vapor cavities to transport thermal power over a distance from an evaporator region of the sealed housing to the heat exchangers. Furthermore, the heat exchangers transfer the thermal power from the sealed housing to an environment external to the heat pipe, and a product of the thermal power and the distance (which is sometimes referred to as the 'heat transport requirement') exceeds a second predetermined value.

For example, the predetermined value may be less than or equal to 1.4 mm and/or the second predetermined value may be larger than or equal to 2,000 W-mm. In some embodiments, the thermal power is greater than or equal to 35 W (such as 40 or 60 W).

Moreover, the thermal transport material may include water.

Furthermore, the sealed housing and the wicking material may include copper. Note that the wicking material may include sintered particles having diameters less than 500 μm.

In some embodiments, the vapor cavities are located at opposite sides of a cross-section of the sealed housing.

Additionally, during operation of the heat pipe, the sealed housing may reduce acoustic sound associated with bubbles of the gas phase of the thermal transport material.

Another embodiment provides a portable electronic device that includes the heat pipe and an integrated circuit that generate heat during operation of the portable electronic device. This integrated circuit may be thermally coupled to the heat pipe, such as proximate to the evaporator region of the sealed housing.

Another embodiment provides a method for cooling a portable electronic device. During operation of the portable electronic device, heat generated by an integrated circuit in the portable electronic device is transported over the distance from the evaporator region of the sealed housing in the heat pipe to the heat exchangers at the condenser regions of the sealed housing. This thermal power is transported via the two-phase bidirectional flow of the thermal transport material in the liquid state and in the gas state in the sealed housing, where the sealed housing has the height less than the predetermined value, and the product of the thermal power and the distance (or effective length) exceeds the second predetermined value. Then, using the heat exchangers, the thermal power is transferred from the sealed housing to the environment external to the portable electronic device.

BRIEF DESCRIPTION OF THE FIGURES

FIG. **1** is a block diagram illustrating a bottom view of a portable electronic device in accordance with an embodiment of the present disclosure.

FIG. **2** is a block diagram illustrating a cross-sectional view of a system for facilitating heat transfer in a portable electronic device in accordance with an embodiment of the present disclosure.

FIG. **3** is a block diagram illustrating a sectional view of a system for facilitating heat transfer in a portable electronic device in accordance with an embodiment of the present disclosure.

FIG. **4** is a block diagram illustrating a side view of a thermal stage in accordance with an embodiment of the present disclosure.

FIG. **5** is a block diagram illustrating a wall in a portable electronic device in accordance with an embodiment of the present disclosure.

FIG. **6** is a block diagram illustrating a rear view of a set of intake and exhaust zones in a portable electronic device in accordance with an embodiment of the present disclosure.

FIG. **7** is a block diagram illustrating a cross-sectional view of a portable electronic device in accordance with an embodiment of the present disclosure.

FIG. **8** is a block diagram illustrating a cross-sectional view of a portable electronic device in accordance with an embodiment of the present disclosure.

FIG. **9** is a block diagram illustrating a gasket in a portable electronic device in accordance with an embodiment of the present disclosure.

FIG. **10** is a block diagram illustrating a flexible portion of a gasket in accordance with an embodiment of the present disclosure.

FIG. **11** is a block diagram illustrating a flexible portion of a gasket in accordance with an embodiment of the present disclosure.

FIG. **12** is a flow chart illustrating a method of facilitating heat transfer in a portable electronic device in accordance with an embodiment of the present disclosure.

FIG. **13** is a flow chart illustrating a method of facilitating heat transfer in a portable electronic device in accordance with an embodiment of the present disclosure.

FIG. **14** is a flow chart illustrating a method of assembling a portable electronic device in accordance with an embodiment of the present disclosure.

FIG. **15** is a block diagram illustrating a top view of a heat pipe in accordance with an embodiment of the present disclosure.

FIG. **16** is a block diagram illustrating a side view of the heat pipe of FIG. **1** in accordance with an embodiment of the present disclosure.

FIG. **17** is a block diagram illustrating a top view of a portable electronic device in accordance with an embodiment of the present disclosure.

FIG. **18** is a flowchart illustrating a method for cooling a portable electronic device in accordance with an embodiment of the present disclosure.

FIG. **19** is a block diagram illustrating a portable electronic device in accordance with an embodiment of the present disclosure.

Note that like reference numerals refer to corresponding parts throughout the drawings. Moreover, multiple instances of the same part are designated by a common prefix separated from an instance number by a dash.

DETAILED DESCRIPTION

FIG. **1** shows a bottom view of a portable electronic device **100**, such as a laptop computer, with the bottom of the enclosure of portable electronic device **100** removed. Within portable electronic device **100**, a number of components may be used to cool heat-generating components such as central-processing units (CPUs), graphics-processing units (GPUs), and/or video memory.

First, portable electronic device **100** may include a set of fans **102-104** for expelling heat generated by the heat-generating components outside portable electronic device **100**. Fans **102-104** may utilize a set of intake and exhaust vents along a wall **118** of portable electronic device **100** to draw in cooler air from outside portable electronic device **100**, circulate the air around the interior of portable electronic device **100** to dissipate heat from the heat-generating components, and expel the heated air out of portable electronic device **100**.

Portable electronic device **100** may also include a heat pipe **106** that conducts heat away from one or more of the heat-generating components toward the flow of exhaust from fans **102-104**. For example, heat pipe **106** may be a sealed pipe of a thermally conductive material, such as copper, filled with a working fluid such as: water, ethanol, acetone, sodium, and/or mercury in a partial vacuum. The working fluid may evaporate to vapor at the thermal interface with a heat-generating component closer to the center of heat pipe **106**, migrate to an end of heat pipe **106** that is cooled by a fan (e.g., fans **102-104**), and condense back into liquid after the heat is removed by the fan. A sintered material (e.g., metal powder) in the interior of heat pipe **106** may then exert capillary pressure on the condensed liquid, conducting the liquid back to the heated portion of heat pipe **106** for subsequent transfer of heat away from the heat-generating component.

To further facilitate heat dissipation from the heat-generating component, a thermal stage **108** may apply a spring force between heat pipe **106** and the heat-generating component. For example, thermal stage **108** may be bonded to heat pipe **106** using a solder and fastened to a surface within portable electronic device **100** using a set of fasteners **110-116** to increase the amount of heat transferred along a thermal interface between the heat-generating component and heat pipe **106**.

In one or more embodiments, heat-dissipation mechanisms and/or components in portable electronic device **100** may include a number of characteristics and/or features that increase the transfer of heat away from the heat-generating components and/or facilitate efficient use of space within portable electronic device **100**. First, fasteners **110-116** may both fasten thermal stage **108** to a surface within portable electronic device **100** and create a thermal gap between heat pipe **106** and the enclosure of portable electronic device **100**, as discussed below with respect to FIG. **2**. Second, thermal stage **108** may include two thicknesses to reduce an overall thickness of portable electronic device **100** while maintaining the spring force necessary to adequately cool the heat-generating component over which thermal stage **108** and heat pipe **106** are disposed, as described in further detail below with respect to FIGS. **3-4**.

Third, wall **118** may include intake vents that are directed at a first angle toward one or more heat-generating components of portable electronic device **100** and exhaust vents directed at a second angle out of portable electronic device **100** to avoid a display of portable electronic device **100**. Wall **118** may also include one or more obstructed vents between the intake and exhaust vents, as well as mechanisms for reducing the temperature of hot spots in the enclosure of portable electronic device **100**. Wall **118** is described in further detail below with respect to FIGS. **5-8**.

Finally, a set of gaskets **120-122** may provide thermal ducts between fans **102-104** and exhaust vents in wall **118** to prevent exhaust from recirculating inside portable electronic device **100** and reducing the effectiveness of heat dissipation from the heat-generating components. As discussed below with respect to FIGS. **9-11**, gaskets **120-122** may include a rigid section that forms the duct, as well as a set of flexible sections that simplify assembly of heat pipe **106** on top of the rigid section and subsequently seal the duct around heat pipe **106**.

FIG. **2** shows a cross-sectional view of a system for facilitating heat transfer in a portable electronic device **200** (e.g., portable electronic device **100** of FIG. **1**). The system includes heat pipe **106** and thermal stage **108**, both of which are disposed over a heat-generating component **202** such as a CPU and/or GPU.

As shown in FIG. **2**, thermal stage **108** may be disposed along a thermal interface in between heat pipe **106** and heat-generating component **202**. A thermal interface material (TIM) **214** may also be disposed within the thermal interface between heat-generating component **202** and thermal stage **108** to increase the thermal contact conductance between heat-generating component **202** and thermal stage **108**.

In one or more embodiments, the spring force of thermal stage **108** is used to increase thermal contact between heat-generating component **202** and heat pipe **106**. For example, thermal stage **108** may improve heat conduction between heat-generating component **202** and heat pipe **106** by reducing the thickness and, in turn, the thermal resistance of TIM **214**. As a result, thermal stage **108** may be made of a material with a high thermal conductivity and spring constant, such as copper titanium.

To provide thermal contact between heat-generating component **202** and heat pipe **106**, heat pipe **106** may be joined to thermal stage **108** using a solder **216-218**, and thermal stage **108** may be fastened to a surface **208** within portable electronic device **200** using a set of fasteners **204-206** (e.g., fasteners **110-116** of FIG. **1**). For example, fasteners **204-206** may include one or more screws that fasten a set of wings of thermal stage **108** to a printed circuit board (PCB) containing heat-generating component **202**. Fasteners **204-206** and thermal stage **108** may thus apply downward force onto heat-generating component **202** and increase the thermal coverage of heat-generating component **202** by heat pipe **106**.

Fasteners **204-206** may additionally form a thermal gap **220** between heat pipe **106** and an enclosure **222** of portable electronic device **200**. Continuing with the above example, screws used to provide fasteners **204-206** may have tall heads **210-212** that provide a 0.5 mm-0.8 mm thermal gap **220** and/or plenum through which air may flow to further cool heat-generating component **202** and/or other heat-generating components in portable electronic device **200**. Alternatively, other types of fasteners **204-206** may be used to provide thermal gap **220**, including: clips, barbed fasteners, bolts, clamps, pins, pegs, and/or clasps.

Thermal gap **220** may also prevent heat pipe **106** from thermally contacting enclosure **222** if portable electronic device **200** is dropped and/or impacts another object. For example, fasteners **204-206** may be placed around heat-generating component **202** if heat-generating component **202** is located relatively far from an attachment point of a metal enclosure **222** to ensure that trampolining in enclosure **222** does not cause heat pipe **106** to transfer heat to enclosure **222** and/or a surface contacting enclosure **222**. Fasteners **204-206** may further be attached to a surface (e.g., the center of a PCB) with lower stiffness so that the impact does not damage heat-generating component **202** and/or other nearby components.

However, the proximity of fasteners **204-206** to enclosure **222** may result in physical contact between fasteners **204-206** and enclosure **222**. For example, fasteners **204-206** may touch enclosure **222** if fasteners **204-206** are designed to be intimate with enclosure **222** and/or if fasteners **204-206** are brought in contact with enclosure **222** during impact between enclosure **222** and a hard object.

As a result, fasteners **204-206** may include an insulating material to prevent fasteners **204-206** from heating enclosure **222** in the event of physical contact between the fasteners **204-206** and enclosure **222**. For example, fasteners **204-206** may be made of plastic to reduce thermal conduction between fasteners **204-206** and enclosure **222**. Consequently, fasteners **204-206** may improve thermal contact between heat-generating component **202** and heat pipe **106**, provide thermal gap **220** as a channel for airflow and/or heat dissipation from heat-generating component **202** and/or heat pipe **106**, and facilitate safe operation of portable electronic device **200** by thermally insulating enclosure **222** from heat-generating component **202** and/or heat pipe **106**.

FIG. **3** shows a sectional view of a system **300** for facilitating heat transfer in a portable electronic device. As mentioned above, system **300** may include heat pipe **106** and thermal stage **108**, both of which are disposed over a heat-generating component **302** (e.g., a CPU). Heat pipe **106** may be soldered to thermal stage **108**, and a set of wings **304-306** of thermal stage **108** may be fastened to a surface within the portable electronic device to apply a spring force to heat-generating component **302**. For example, the fastening of wings **304-306** that are angled upward to a PCB containing heat-generating component **302** may apply a downward force onto heat-generating component **302** and increase the thermal contact conductance between heat-generating component **302** and heat pipe **106**.

FIG. **4** shows a side view of thermal stage **108**. Thermal stage **108** may include a number of regions **404-406** with different thicknesses. In particular, region **402** may be of a first thickness, and regions **404-406** may be of a second thickness that is greater than the first thickness.

The first and/or second thicknesses may be created in thermal stage **108** using a number of techniques. For example, a machining technique may be used to form a trough in a material (e.g., copper titanium) of uniform stock thickness. Similarly, a profile corresponding to the first thickness may also be formed in raw stock using a rolling technique. The first thickness may further be created by removing material from uniform stock using a skiving technique, continuous machining technique, and/or chemical-etching technique. A forging and/or coining technique may be used to press the first thickness into uniform stock, or a casting technique may be used to form the first and second thicknesses from a mold.

As mentioned above, the first thickness may accommodate a heat pipe (e.g., heat pipe **106** of FIG. **1**). For example, the first thickness may form a notch and/or groove within which the heat pipe may be placed to reduce an overall thickness of the portable electronic device containing thermal stage **108** and the heat pipe. On the other hand, the second thickness may increase a spring force between a heat-generating component and the heat pipe, allowing for better thermal transfer between the heat-generating component (e.g., a high-power CPU) and the heat pipe. For example, the second thickness may be used in the wings (e.g., wings **304-306** of FIG. **3**) of thermal stage **108** to increase the downward force applied by thermal stage **108** and/or a set of fasteners (e.g., fasteners **110-116** of FIG. **1**) onto the top of the heat-generating component. Consequently, the first and second thicknesses may facilitate both efficient use of space within the portable electronic device and increased cooling of the heat-generating component by the heat pipe.

FIG. **5** shows wall **118**. Wall **118** may be a rear wall of a portable electronic device, such as a laptop computer. The rear wall may be integrated into a top case of the laptop computer to reduce the number of seams and/or components in the laptop computer's enclosure. For example, instead of creating wall **118** as a separate part and subsequently joining wall **118** to the top case, wall **118** may be machined out of the top case. In turn, the reduced number of seams and/or components in the enclosure may mitigate electromagnetic interference caused by the enclosure and/or improve the rigidity and/or height tolerance of the enclosure.

As shown in FIG. **5**, wall **118** includes an intake zone **502** and two exhaust zones **504-506**. Intake zone **502** includes a set of intake vents around the center of wall **118** that allow a set of fans (e.g., fans **102-104** of FIG. **1**) to draw cooler air from the exterior of the portable electronic device into the portable electronic device. The fans may then circulate the air inside a set of plenums and/or thermal gaps (e.g., thermal gap **220** of FIG. **2**) within the portable electronic device and expel the heated air out of the portable electronic device through a set of exhaust vents in exhaust zones **504-506** on either side of intake zone **502**. As discussed in further detail below with respect to FIGS. **7-8**, the intake vents may be directed at a first angle toward one or more heat-generating components of the portable electronic device, and the exhaust vents may be directed at a second angle out of the portable electronic device.

FIG. **6** shows a rear view of a set of intake and exhaust zones **502-506** of a portable electronic device. As described above, intake zone **502** may include a set of intake vents that are used by fans to draw in air from outside the portable electronic device, while each exhaust zone **504-506** may include a set of exhaust vents that are used by the fans to expel heated air out of the portable electronic device.

In addition, a set of obstructed vents **602-608** may separate intake zone **502** from exhaust zones **504-506**. Air flow from vents **602-608** may be blocked from the inside of the portable electronic device by a portion of a duct formed by a gasket in the portable electronic device, as described below with respect to FIG. **10**. Such obstruction of substantially evenly spaced openings in intake and exhaust zones **502** and exhaust zones **504-506** may maintain the cosmetic continuity of the vents in intake and exhaust zones **502-506**, reduce electromagnetic interference from the enclosure of the portable electronic device, and facilitate heat dissipation in the portable electronic device by separating the intake and exhaust flows passing through intake and exhaust zones **502-506**, respectively.

FIG. **7** shows a cross-sectional view of a portable electronic device **700**. More specifically, FIG. **7** shows a cross-sectional view of an exhaust vent **702** from an exhaust zone (e.g., exhaust zones **504-506** of FIG. **5**) in a wall (e.g., wall **118** of FIG. **1**) of portable electronic device **700**. Air from the interior of portable electronic device **700** may be moved by a fan (e.g., fans **102-104** of FIG. **1**) across heat pipe **106** and a heat sink **712**, where the air is heated and expelled as exhaust out of exhaust vent **702**.

In addition, two flows **704-706** of exhaust out of vent **702** may be created by a clutch barrel **710** connecting a display of portable electronic device **700** (e.g., a laptop computer) to the bottom portion of portable electronic device **700**. Flow **704** may exit portable electronic device **700** along the bottom of clutch barrel **710**, while flow **706** may exit portable electronic device **700** over the top of clutch barrel **710**. To prevent exhaust from changing the white point of and/or accelerating degradation in the display, exhaust vent **702** may be directed at an angle out of portable electronic device **700** so that exhaust flows **704-706** avoid the display and/or do not create a large temperature gradient across the display. If the display is closed over the bottom portion of portable electronic device **700**, flow **706** may cease, and all exhaust may be expelled out of vent **702** through an air gap between the bottom of portable electronic device **700** and clutch barrel **710**.

Those skilled in the art will appreciate that exhaust flowing out of exhaust vent **702** may also heat material in the wall near exhaust vent **702** and create a hot spot in the enclosure of portable electronic device **700**. As a result, a T-cut **708** may be made in the material to reduce the thickness of the material and, in turn, the transfer of heat through the material. At the same time, the thickness of the material between exhaust vent **702** and one or more intake vents in portable electronic device **700** may be maintained to facilitate lateral conduction of heat from exhaust vent **702** to the intake vent(s), thus further reducing the temperature of the hot spot. Consequently, the relatively large size of exhaust vent **702**, T-cut **708**, and/or ridges at the bottom of exhaust vent **702** may provide a lightweight structure with thermally minimal spars, a reduced conduction path to both the top and bottom enclosures of portable electronic device **700**, and a lateral conduction path between the exhaust and intake zones in the wall.

FIG. **8** shows a cross-sectional view of a portable electronic device **800**. In particular, FIG. **8** shows a cross-sectional view of an intake vent **802** from an intake zone (e.g., intake zone **502** of FIG. **5**) in a wall (e.g., wall **118** of FIG. **1**) of portable electronic device **800**. Intake vent **802** may allow cooler air from outside portable electronic device **800** to be drawn into portable electronic device **800** by a fan (e.g., fans **102-104** of FIG. **1**) and circulated within portable electronic device **800** before being expelled as exhaust out of one or more exhaust vents (e.g., exhaust vent **702** of FIG. **7**) in the wall.

Two flows **804-806** of air may pass through intake vent **802** while a display of portable electronic device **800** (e.g., a laptop computer) is open. Flow **804** may enter portable electronic device **800** along the bottom of a clutch barrel **810** connecting the display to the bottom of portable electronic device **800**, while flow **806** may enter portable electronic device **800** from the top of clutch barrel **810**. If the display is closed over the bottom of portable electronic device **800**, flow **806** may cease, and all air drawn in through intake vent **802** may flow **804** from an air gap between the bottom of portable electronic device **800** and clutch barrel **810**.

Moreover, intake vent **802** may be directed at an upward angle toward a heat-generating component **808** of portable electronic device **800** to facilitate heat dissipation from heat-generating component **808**. For example, intake vent **802** may channel air over the top of a PCB containing video memory to cool the video memory and/or other heat-generating components at the top of the PCB. As a result, air passing through intake vent **802** may dissipate heat from heat-generating component **808** better than air passing through an intake vent that is not angled upwards into the interior of portable electronic device **800**.

FIG. **9** shows a gasket **902** (e.g., gaskets **120-122** of FIG. **1**) in a portable electronic device. As mentioned above, gasket **902** may form a thermal duct between a fan **910** and a set of exhaust vents in wall **118** to prevent exhaust from recirculating inside the portable electronic device and reducing the effectiveness of heat dissipation from heat-generating components in the portable electronic device.

As shown in FIG. **9**, gasket **902** may include three portions **904-908**. A rigid portion **904** may be disposed around a bottom of heat pipe **106** to form the duct between fan **910** and wall **118**. Two flexible portions **904-906** may then be bonded to rigid portion **904** so that gasket **902** is manufactured as a single component instead of multiple components that require multiple steps to assemble into gasket **902**. For example, flexible portions **904-906** may be made of a rubber that is bonded to a rigid portion **904** made of plastic using an overmolding technique.

Portion **906** may be a flap that is open during assembly of heat pipe **106** in the portable electronic device to allow heat pipe **106** to be placed over portions **904** and **908**. Portion **906** may then be closed over heat pipe **106** and portions **904** and **908** to seal the duct around heat pipe **106** after the assembly. Portions **904-906** may further seal the duct around fan **910**, a bottom enclosure (not shown) of the portable electronic device, a top enclosure **912** of the portable electronic device, and/or exhaust vents in wall **118**. For example, portion **906** may fold over portions **904** and **908** to seal along the top of fan **910**, the top and/or sides of heat pipe **106**, and/or the bottom enclosure. On the other hand, portion **908** may be bonded to one or more edges of portion **904** and seal along the bottom of fan **910**, the bottom and/or sides of heat pipe **106**, top enclosure **912**, and/or wall **118**. Gasket **902** may also include an additional flexible portion **914** that seals the duct along wall **118**. Alternatively, portion **914** may be provided by a separate component (e.g., a gasket) disposed between gasket **902** and wall **118**.

FIG. **10** shows flexible portion **906** of a gasket (e.g., gasket **902** of FIG. **9**). As mentioned above, portion **906** includes a flap that is open during assembly of heat pipe **106** in the portable electronic device. For example, the portable electronic device may be assembled by placing the gasket into the top enclosure of the portable electronic device with portion **906** open over wall **118**. After the gasket is placed into the top enclosure of the portable electronic device, a part of rigid portion **904** may obstruct one or more vents in wall **118** to separate the intake and exhaust zones of wall **118**. Next, fan **910** may be placed next to the gasket, and heat pipe **106** may be placed on top of rigid portion **904** and/or a second flexible portion (e.g., portion **908** of FIG. **9**) of the gasket.

FIG. **11** shows flexible portion **906** of a gasket (e.g., gasket **902** of FIG. **9**). As shown in FIG. **11**, portion **906** may be closed over heat pipe **106**, rigid portion **904**, and the second flexible portion after heat pipe **106** is assembled in the portable electronic device. The bottom enclosure of the portable electronic device may then be placed over the gasket to create a compression seal around heat pipe **106**, fan **910**, one or more exhaust vents of wall **118**, and/or the top enclosure of the portable electronic device. In addition, the insulating materials used in the gasket may restrict heat transfer between the exhaust and the enclosure of the portable electronic device, thus facilitating safe operation of the portable electronic device.

FIG. **12** shows a flow chart illustrating a method **1200** of facilitating heat transfer in a portable electronic device. During this method, a first thickness to accommodate a heat pipe in the portable electronic device and a second thickness that is greater than the first thickness to increase a spring force between the heat-generating component and the heat pipe are provided in a thermal stage (operation **1202**). The thermal stage may be made of copper titanium and/or another material with a high thermal conductivity and/or spring constant. The first and/or second thicknesses may be created using a machining technique, a rolling technique, a skiving technique, a forging technique, a coining technique, a chemical etching technique, and/or a casting technique.

Next, a TIM is disposed between the heat-generating component and the thermal stage (operation **1204**). For example, the TIM may be applied to a surface of the heat-generating component and/or the thermal stage. The thermal stage is then disposed along a thermal interface between the heat-generating component and the heat pipe (operation **1206**), and the heat pipe is joined to the thermal stage using a solder (operation **1208**). For example, the thermal stage may be placed over the heat-generating component, and the heat pipe may be placed over the thermal stage and soldered to the thermal stage.

The thermal stage is also fastened to a surface within the portable electronic device using a set of fasteners (operation **1210**), and the set of fasteners is used to form a thermal gap between the heat pipe and the enclosure of the portable electronic device (operation **1212**). For example, the fasteners may include screws with tall heads that form a plenum between the heat pipe and enclosure through which air may flow to further dissipate heat from the heat-generating component. The screws may also separate the heat pipe from the enclosure, thus preventing the heat pipe from transmitting large amounts of heat through the enclosure. Similarly, the heads of the screws may include an insulating material such as plastic to prevent the heat-generating component from thermally contacting the enclosure if the enclosure touches the screws' heads (e.g., as a result of impact between the portable electronic device and a hard surface and/or by design).

FIG. **13** shows a flow chart illustrating a method **1300** of facilitating heat transfer in a portable electronic device. During this method, a wall of the portable electronic device that includes an intake zone containing a set of intake vents directed at a first angle toward one or more heat-generating components of the portable electronic device and an exhaust zone containing a set of exhaust vents directed at a second angle out of the portable electronic device is provided (operation **1302**). For example, the wall may be a rear wall that is integrated into a top case of a laptop computer. The first angle may facilitate the cooling of components at the top of a PCB in the laptop computer, while the second angle may direct exhaust out of the laptop computer so that the exhaust avoids the display of the laptop computer.

Next, one or more vents between the intake zone and exhaust zone are obstructed (operation **1304**). The vents may be obstructed by a portion of a duct between a fan and the exhaust zone and/or another component in the portable electronic device. The obstructed vents may maintain the cosmetic continuity of the portable electronic device while separating the intake and exhaust flows passing through the intake and exhaust zones.

Material adjacent to the exhaust vent may also be removed to reduce a temperature of a hot spot in the material during the transfer of exhaust out of the portable electronic device (operation **1306**). For example, the material may be removed using a T-cut to reduce the amount of heat conducted through the material to the outside of the portable electronic device's enclosure. The temperature of the hotspot may further be reduced by maintaining the thickness of the material between the exhaust vent and one or more intake vents (operation **1308**) in the portable electronic device. For example, the thickness of material separating the exhaust vent from an intake vent to the side of the exhaust vent may be maintained to facilitate lateral conduction of heat from the exhaust vent to the intake vent.

FIG. **14** shows a flow chart illustrating a method **1400** of assembling a portable electronic device. During this method, a gasket containing a rigid portion forming a duct between a fan and exhaust vent of the portable electronic device, with a first flexible portion containing a flap, and a second flexible portion bonded to one or more edges of the rigid portion, is placed within an enclosure of the portable electronic device (operation **1402**). For example, the gasket may be placed inside a top enclosure of the portable electronic device so that one end of the gasket is flush with a wall (e.g., wall **118** of FIG. **1**) containing the exhaust vent, and a fan may be installed in the portable electronic device so that the other end of the gasket is flush with the fan. The rigid portion may be made of plastic, while the first and second flexible portions may be made of a rubber that is bonded to the rigid portion using an overmolding technique.

Next, a heat pipe is disposed over the rigid portion and second flexible portion while the flap is open (operation **1404**). For example, the heat pipe may be assembled in the portable electronic device so that the heat pipe rests on top of the rigid portion and second flexible portion while the flap is open over the wall.

Moreover, the flap is closed over the heat pipe, the rigid portion, and the second flexible portion to seal the duct around the heat pipe (operation **1406**). The first and second flexible portions may also seal the duct around the fan, the bottom enclosure of the portable electronic device, the top enclosure of the portable electronic device, and/or the exhaust vent. The gasket may thus prevent recirculation of exhaust within the portable electronic device, simplify the assembly of the heat pipe and/or portable electronic device, and/or insulate the enclosure of the portable electronic device from the heated exhaust.

We now describe additional embodiments. FIG. **15** presents a block diagram illustrating a top view of a heat pipe **1500** that facilitates passive heat transfer. This heat pipe includes a sealed housing **1510**, having ends **1512**, which includes a thermal transport material (as described below with reference to FIG. **16**). Moreover, heat pipe **1500** includes heat exchangers **1514** (such as convective-cooling fins) that are thermally coupled to sealed housing **1510** at condenser regions **1516** of sealed housing **1510** proximate to ends **1512**.

As shown in FIG. **16**, which presents a block diagram illustrating a side view of heat pipe **1500**, sealed housing **1510** has an outer surface **1610** and an inner surface **1612**, as well as ends **1512** (FIG. **15**). Furthermore, a height **1614** of sealed housing **1510** may be less than a predetermined value (such as less than or equal to 1.4 mm). For example, height **1614** may be 1.2 mm. This reduced height may facilitate the use of heat pipe **1500** in portable electronic devices with reduced form factors (as described further below with reference to FIG. **17**).

In existing heat pipes, reducing height **1614** to the predetermined value would adversely impact the heat-transport capability. However, the internal structure of heat pipe **1500** facilitates improved heat-transport capability at heights as small as 1.2 mm (or smaller). In particular, sealed housing **1510** includes a wicking material **1616** along at least a portion of inner surface **1612** and vapor cavities **1618** (where there is no wicking material **1616**), and sealed housing **1510** includes a thermal transport material in a liquid state, such as water.

The geometry of this internal structure (such as the geometries of wicking material **1616** and vapor cavities **1618**) may be optimized to maximize the thermal power transported by heat pipe **1500**. As illustrated in FIG. **16**, in an exemplary embodiment vapor cavities **1618** are located at opposite sides of a cross-section of sealed housing **1510**, and wicking material **1616** may be along at least a portion of inner surface **1612**. A width **1622** of wicking material **1616** may be between 10 and 90% of width **1624** of sealed housing **1510**, while width **1624** may be 11-12 mm. Moreover, a height **1620** of wicking material **1616** may be between 10-90% of height **1614**. Furthermore, a thickness **1626** of sealed housing **110** may be between 0.1-0.5 mm, and wicking material **1616** may include sintered particles having diameters less than 500 μm. In some embodiments, sealed housing **1510** and wicking material **1616** may include copper (for example, they may be made of copper or a copper alloy).

During operation of heat pipe **1500**, sealed housing **1510** supports a two-phase bidirectional flow of thermal transport material in the liquid state in wicking material **1616** and in a gas state in vapor cavities **1618**. Referring to FIG. **15**, thermal power (such as that associated with operation of one or more integrated circuits and, more generally, one or more components) is conductively coupled to sealed housing **1510** at evaporator region **1520** of sealed housing **1510**. Heat associated with the thermal power converts some of the thermal transport material from the liquid state to the gas state. The gas transports the thermal power from evaporator region **1520** to condenser regions **1516**, where it is transferred to heat exchangers **1514**. In the process, the thermal transport material condenses back into the liquid state, where a return flow to evaporator region **1520** occurs in wicking material **1616** in FIG. **16**. Thus, the two-phase bidirectional flow transports thermal power over distances **1518** from an evaporator region **1520** to heat exchangers **1514**.

Furthermore, heat exchangers **1514** transfer the thermal power from sealed housing **1510** to an environment external to heat pipe **1500** (for example, in conjunction with forced-fluid drivers, such as fans, that force air over heat exchangers **1514**), and a product of the thermal power and a distance (or effective length) equal to two times either of distances **1518** exceeds a predetermined value, which may be larger than or equal to 2,000 W-mm (such as 2,030 or 3,050 W-mm). For example, distances **1518** may each be 120 mm (so that two times either of distances **1518** is 240 mm), and the thermal power may be greater than or equal to 35 W (such as 40 or 60 W) with a heat flux of more than 27 W/cm^2 (such as 32 or 34 W/cm^2)

Note that heat pipe **1500** may also be designed so that, during operation of heat pipe **1500**, sealed housing **1510** may reduce acoustic sound associated with bubbles of the gas phase of thermal transport material. For example, the geometry of wicking material **1616** and vapor cavities **1618** in FIG. **16** may be selected so that the bubbling noise that can occur as the gas phase moves through the liquid phase of the thermal transport material is reduced or eliminated.

Heat pipe **1500** may be included in an electronic device, such as a portable electronic device. This is shown in FIG. **17**, which presents a block diagram illustrating a top view of portable electronic device **1700** that includes heat pipe **1500**. Moreover, integrated circuit (I.C.) **1710**, which generates heat during operation of portable electronic device **1700**, may be thermally coupled to heat pipe **1500** proximate to evaporator region **1520** of sealed housing **1510**. For example, integrated circuit **1710** may be thermally coupled to heat pipe **1500** by an intervening copper plate (not shown). In this way, thermal power may be transferred to heat pipe **1500**, which, as described previously, then passively conveys it out of portable electronic device **1700**.

We now describe embodiments of a method that can be performed using the preceding embodiments. FIG. **18** presents a flowchart illustrating a method **1800** for cooling a portable electronic device, such as portable electronic device **1700** (FIG. **17**). During operation of the portable electronic device, heat generated by an integrated circuit in the portable electronic device is transported over the distance from the evaporator region of the sealed housing in the heat pipe to the heat exchangers at the condenser regions of the sealed housing (operation **1810**). This thermal power is transported via the two-phase bidirectional flow of the thermal transport material in the liquid state and in the gas state in the sealed housing, where the sealed housing has the height less than the predetermined value, and the product of the thermal power and the distance (or effective length) exceeds the second predetermined value. Then, using the heat exchangers, the thermal power is transferred from the sealed housing to the environment external to the portable electronic device (operation **1812**).

In some embodiments of methods **1200** (FIG. **12**), **1300** (FIG. **13**), **1400** (FIG. **14**) or **1800** there may be additional or fewer operations. Moreover, the order of the operations may be changed, and/or two or more operations may be combined into a single operation.

The above-described heat transfer mechanisms can generally be used in any type of electronic device. For example, FIG. **19** illustrates a portable electronic device **1900** which includes a processor **1902**, a memory **1904** and a display **1908**, which are all powered by a battery **1906**. This portable electronic device may include: one or more program modules or sets of instructions stored in an optional memory subsystem (not shown). These sets of instructions may be executed by an optional processing subsystem (such as one or more processors) on a motherboard (not shown). Note that the one or more computer programs may constitute a computer-program mechanism. Moreover, instructions in the various modules in the optional memory subsystem may be implemented in: a high-level procedural language, an object-oriented programming language, and/or in an assembly or machine language. Furthermore, the programming language may be compiled or interpreted, e.g., configurable or configured, to be executed by the optional processing subsystem.

In some embodiments, functionality in these circuits, components and devices may be implemented in one or more: application-specific integrated circuits (ASICs), field-programmable gate arrays (FPGAs), and/or one or more digital signal processors (DSPs). Moreover, the circuits and components may be implemented using any combination of analog and/or digital circuitry, including: bipolar, PMOS and/or NMOS gates or transistors. Furthermore, signals in these embodiments may include digital signals that have approximately discrete values and/or analog signals that have continuous values. Additionally, components and circuits may be single-ended or differential, and power supplies may be unipolar or bipolar.

Portable electronic device **1900** may include one of a variety of devices that can include memory, including: a laptop computer, a media player (such as an MP3 player), an appliance, a subnotebook/netbook, a tablet computer, a smartphone, a cellular telephone, a network appliance, a personal digital assistant (PDA), a toy, a controller, a digital signal processor, a game console, a device controller, a computational engine within an appliance, a consumer-electronic device, a portable computing device, a digital camera, a personal organizer, and/or another electronic device, such as another type of battery-powered electronic device.

In order to cool heat-generating components in portable electronic device **1900**, portable electronic device **1900** may include a heat pipe that conducts heat away from the heat-generating components and/or one or more fans that expel the heat out of portable electronic device **1900**.

Portable electronic device **1900** may also include a thermal stage disposed along a thermal interface between a heat-generating component and the heat pipe. The thermal stage may include a first thickness to accommodate the heat pipe and a second thickness that is greater than the first thickness to increase the spring force between the heat-generating component and the heat pipe. The thermal stage may also be fastened to a surface within portable electronic device **1900** by a set of fasteners that form a thermal gap between the heat pipe and the enclosure of portable electronic device **1900**.

Moreover, in order to further facilitate cooling of the heat-generating components, a wall of portable electronic device **1900** may include an intake zone containing a set of intake vents directed at a first angle toward one or more of the heat-generating components. The wall may also include an exhaust zone containing a set of exhaust vents directed at a second angle out of the electronic device (e.g., to avoid a display of the electronic device). One or more vents may be obstructed between the intake and exhaust zones to separate the intake and exhaust zones. In addition, the temperature of a hot spot near an exhaust vent may be reduced by removing material adjacent to the exhaust vent and/or maintaining a thickness of the material between the exhaust vent and one or more intake vents.

Furthermore, a gasket may prevent the recirculation of exhaust inside the electronic device. The gasket may include a rigid portion that forms a duct between a fan and an exhaust vent. The gasket may also include a first flexible portion bonded to the rigid portion, as well as a second flexible portion bonded to one or more edges of the rigid portion. The first flexible portion may be a flap that is open during assembly of the heat pipe in the electronic device and closed over the heat pipe and the rigid portion to seal the duct around the heat pipe after the assembly. The first and second flexible portions may further seal the duct around the fan, the bottom enclosure of the electronic device, the top enclosure of the electronic device, and/or the exhaust vent.

While a portable electronic device was used as an illustration in the preceding discussion, in other embodiments the heat-transfer technique is included in an electronic device, such as a server, a desktop computer, a mainframe computer and/or a blade computer. Furthermore, alternative heat transfer components and/or materials may be used in heat pipe **1500** (FIG. **15**).

Additionally, one or more of the components may not be present in the FIGS. **1-11** and **15-17**. In some embodiments, the preceding embodiments include one or more additional components that are not shown in FIGS. **1-11** and **15-17**.

Also, although separate components are shown in FIGS. **1-11** and **15-17**, in some embodiments some or all of a given component can be integrated into one or more of the other components and/or positions of components can be changed.

In the preceding description, we refer to 'some embodiments.' Note that 'some embodiments' describes a subset of all of the possible embodiments, but does not always specify the same subset of embodiments.

The foregoing description is intended to enable any person skilled in the art to make and use the disclosure, and is provided in the context of a parti-cular application and its requirements. Moreover, the foregoing descriptions of embodiments of the present disclosure have been presented for purposes of illustration and description only. They are not intended to be exhaustive or to limit the present disclosure to the forms disclosed. Accordingly, many modifications and variations will be apparent to practitioners skilled in the art, and the general principles defined herein may be applied to other embodiments and applications without departing from the spirit and scope of the present disclosure. Additionally, the discussion of the preceding embodiments is not intended to limit the present disclosure. Thus, the present disclosure is not intended to be limited to the embodiments shown, but is to be accorded the widest scope consistent with the principles and features disclosed herein.

What is claimed is:

1. A component in an electronic device, comprising a gasket, wherein the gasket includes:

a rigid portion disposed around a bottom of a heat pipe, wherein the rigid portion forms a duct between a fan and an exhaust vent of the electronic device; and

a first flexible portion bonded to the rigid portion, wherein the first flexible portion comprises a flap that is open during assembly of the heat pipe in the electronic device and closed over the heat pipe and the rigid portion to seal the duct around the heat pipe after the assembly.

2. The component of claim **1**, wherein the gasket further comprises a second flexible portion bonded to one or more edges of the rigid portion, wherein the second flexible portion contacts the first flexible portion and the heat pipe to further seal the duct around the heat pipe.

3. The component of claim **2**, wherein the first and second flexible portions further seal the duct around at least one of:

the fan;

a bottom enclosure of the electronic device;

a top enclosure of the electronic device; and

the exhaust vent.

4. The component of claim **2**, wherein the first and second flexible portions are bonded to the rigid portion using an overmolding technique.

5. The component of claim **2**, wherein the first and second flexible portions form a compression seal around the heat pipe.

6. The component of claim **1**, wherein the rigid portion comprises plastic.

7. The component of claim **1**, wherein the first flexible portion comprises a rubber.

8. The component of claim **1**, wherein the gasket is separate from the fan.

9. The component of claim **1**, wherein the flap is open at a first configuration of the component and closed at a second configuration of the component.

10. The component of claim **1**, wherein the flap rotates from being open to being closed.

11. The component of claim **1**, wherein the gasket prevents exhaust from the fan from recirculating within the electronic device.

12. A method for assembling an electronic device, comprising:

placing a gasket within an enclosure of the electronic device, wherein the gasket comprises:

a rigid portion, wherein the rigid portion forms a duct between a fan and an exhaust vent of the electronic device;

a first flexible portion bonded to the rigid portion, wherein the first flexible portion comprises a flap that is open during assembly of the electronic device; and

a second flexible portion bonded to one or more edges of the rigid portion;

disposing a heat pipe over the rigid portion and the second flexible portion while the flap is open, wherein the rigid portion is disposed around a bottom of the heat pipe; and

closing the flap over the heat pipe, the rigid portion, and the second flexible portion to seal the duct around the heat pipe.

13. The method of claim **12**, wherein the first and second flexible portions further seal the duct around at least one of:

the fan;

a bottom enclosure of the electronic device;

a top enclosure of the electronic device; and

the exhaust vent.

14. The method of claim **12**, wherein the first and second flexible portions are bonded to the rigid portion using an overmolding technique.

15. The method of claim **12** wherein the first and second flexible portions form a compression seal around the heat pipe.

16. The method of claim **12**, wherein the rigid portion comprises plastic.

17. The method of claim **12**, wherein the first and second flexible portions comprise a rubber.

18. An electronic device, comprising:

a heat-generating component;

a heat pipe configured to conduct heat away from the heat-generating component;

a fan configured to transfer heat from the heat pipe out of the electronic device; and

a gasket, comprising:

a rigid portion disposed around a bottom of the heat pipe, wherein the rigid portion forms a duct between the fan and an exhaust vent of the electronic device; and

a first flexible portion bonded to the rigid portion, wherein the first flexible portion comprises a flap that is open during assembly of the heat pipe in the electronic device and closed over the heat pipe and the rigid portion to seal the duct around the heat pipe after the assembly.

19. The electronic device of claim **18**, wherein the gasket further comprises a second flexible portion bonded to one or more edges of the rigid portion, wherein the second flexible portion contacts the first flexible portion and the heat pipe to further seal the duct around the heat pipe.

20. The electronic device of claim **19**, wherein the first and second flexible portions further seal the duct around at least one of:

the fan;

a bottom enclosure of the electronic device;

a top enclosure of the electronic device; and

the exhaust vent.

21. The electronic device of claim **19**, wherein the first and second flexible portions are bonded to the rigid portion using an overmolding technique.

22. The electronic device of claim **19**, wherein the first and second flexible portions form a compression seal around the heat pipe.

23. The electronic device of claim **18**, wherein the rigid portion comprises plastic.

24. The electronic device of claim **18**, wherein the first flexible portion comprises a rubber.

25. The electronic device of claim **18**, wherein the electronic device is a laptop computer.

26. The electronic device of claim **18**, wherein the gasket is separate from the fan.

27. The electronic device of claim **18**, wherein the flap is open at a first configuration of the component and closed at a second configuration of the component.

28. The electronics device of claim **18**, wherein the flap rotates from being open to being closed.

29. The electronic device of claim **18**, wherein the gasket prevents exhaust from the fan from recirculating within the electronic device.

* * * * *